CANADA
DEPARTMENT OF MINES
AND
TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
WATER SUPPLY PAPER No. 310

GROUND-WATER RESOURCES OF MATILDA TOWNSHIP, DUNDAS COUNTY, ONTARIO

By
E. B. Owen

OTTAWA
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INTRODUCTION

This report deals with the ground-water conditions of a township in the province of Ontario investigated by the Geological Survey of Canada. It is one of a series of ground-water reports on individual townships of Ontario.

All available information pertaining to the water wells in the area was recorded and water samples were taken for analysis. The elevation of the surface of the water in most of the wells was measured. As the ground-water conditions are directly related to the geology, the surface deposits were also studied and mapped.

Thanks are here extended to the farmers and to the residents of communities throughout the area for their co-operation and willingness to supply information regarding their wells. Valuable assistance was also given by well drillers and municipal waterworks authorities in the area.

Publication of Results

The essential information pertaining to ground-water conditions is being issued in reports covering each township investigated in the province of Ontario. These reports, as published, will be supplied directly to the proper municipal and township authorities. In addition, pertinent data on wells investigated in each township will be kept on file at Ottawa. The well record compilation sheets will not ordinarily accompany the reports, as, for most areas, they are too numerous. However, persons interested in individual wells may receive the information upon application to the Chief Geologist, Geological Survey of Canada, Ottawa. For this information the request should specify lot, concession, owner's name, and approximate location of the well -- at house, at barn, in pasture, etc.

With each report is a map consisting of two figures. Figure 1 shows the surface deposits that will be encountered in the

area, and Figure 2 shows the positions of all wells for which records are available, together with the class of the well at each location.

GLOSSARY OF TERMS USED

Alluvium. Recent deposits of clay, silt, sand, gravel, and other material deposited in lake beds and in flood-plains of modern streams.

Aquifer. A porous bed, lens, pocket, or deposit of material that transmits water in sufficient quantity to satisfy pumping wells, flowing artesian wells, and springs.

Bedrock. Bedrock, as here used, refers to the consolidated deposits underlying the glacial drift. South of a line drawn between Midland, on Georgian Bay, and Kingston, the bedrock consists mainly of sedimentary rocks such as limestone, shale, slate, and sandstone; north of that line the bedrock consists chiefly of hard, crystalline, granitic rocks.

Contour. A line drawn on a map that passes through points that have the same elevation above mean sea-level.

Continental Ice-sheet. The great, broad ice-sheet that covered most of the surface of Canada many thousands of years ago.

Escarpment. A cliff or relatively steep slope separating two level or gently sloping areas.

Effluent Stream. A stream that receives water from a zone of saturation.

Flood-plain. A flat part in a river valley ordinarily above water, but covered with water when the river is in flood.

Glacial Drift. A general term that includes all the loose, unconsolidated materials that were deposited by the continental ice-sheet, or by waters associated with it. It includes till, deposits of stratified drift, and scattered boulders and rock fragments.

Several forms in which glacial drift occurs are as follows:

(1) End Moraine (Terminal Moraine). A more or less discontinuous ridge or series of ridges consisting of glacial drift that was laid down by the ice at the margin of a moving ice-sheet. The surface is characterized by irregular hills and undrained basins.

(2) Ground Moraine. A widely distributed moraine consisting of glacial drift deposited beneath an ice-sheet. The predominant material is till, which is clay containing stones. The topography may vary from flat to gently rolling.

(3) Kame Moraine. Assorted deposits of sandy and gravelly stratified drift laid down at or close to the ice margin. The topography is similar to that of an end moraine. Kame terraces are elongated deposits of this type laid down on the slopes of broad, flat-bottomed valleys.

(4) Drumlin. A smooth oval hill that has its long axis parallel with the direction of ice movement at that place. It is composed mainly of till.

(5) Esker. An irregular-crested ridge or series of discontinuous ridges of stratified drift deposited by a glacial stream that flowed beneath the continental ice-sheet or in deep crevasses within it. It is composed mainly of sand and gravel.

(6) Glacio-fluvial Deposits. Silt, sand, and gravel outwash deposited by streams resulting from the melting of the ice-sheet.

(7) Glacio-lacustrine Deposits. Clay, silt, and sand deposited in glacial lakes during the retreat of the ice-sheet. The clay deposits are commonly very distinctly stratified in layers a fraction of an inch to one or more feet in thickness; each layer is believed to represent deposition during one summer season and one winter season.

(8) Kame. An isolated mound or conical hill composed of stratified sand and gravel deposited in a crack or crevasse within the ice or in a depression along the ice front.

(9) Marine Deposits. Deposits laid down in the sea during the submergence that followed the withdrawal of the last ice-sheet. They consist chiefly of clay, silt, and sand, and have emerged beaches of sand and gravel associated with them.

(10) Shoreline. A discontinuous escarpment that indicates the former margin of a glacial lake or sea. It is accompanied by scattered deposits of sand and gravel located on former beaches and bars.

Ground Water. Sub-surface water in the zone of saturation below the water-table.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it was first encountered.

Influent Stream. A stream that feeds water into a zone of saturation.

Impervious or Impermeable. Beds such as fine clays or shale are considered to be impervious or impermeable when they do not permit the perceptible passage or movement of ground water.

Pervious or Permeable. Beds are pervious or permeable when they permit the perceptible passage or movement of ground water, as, for example, porous sand, gravel, and sandstone.

Porosity. The porosity of a rock is its property of containing interstices or voids.

Pre-glacial Land Surface. The surface of the land as it existed before the ice-sheet covered it with drift.

Recent Deposits. Deposits that have been laid down by the agencies of water and wind since the disappearance of the continental ice-sheet; for example, alluvium in stream valleys.

Unconsolidated Deposits. The mantle or covering of loose, uncemented material overlying the bedrock. It consists of Glacial or Recent deposits of boulders, gravel, sand, silt, and clay.

Water-table. The upper limit of the part of the ground saturated with water. This may be near the surface or many feet below it. Water may be retained above the main water-table by a zone of impervious material; such water is said to be perched and its upper limit to be a perched water-table.

Wells. Holes sunk into the ground so as to obtain a supply of water. When no water is obtained they are referred to as dry holes. Wells yielding water are divided into four classes:

(1) Flowing Artesian Wells. Wells in which the water is under sufficient hydrostatic pressure to flow above the surface of the ground at the well.

(2) Non-flowing Artesian Wells. Wells in which the water is under hydrostatic pressure sufficient to raise it above the level of the aquifer, but not above the level of the ground at the well.

(3) Non-artesian Wells. Wells in which the water does not rise above the water-table or the aquifer.

(4) Intermittent Non-artesian Wells. Wells that are generally dry for a part of each year.

Zone of Saturation. The part of the ground, below a water-table that is saturated with water.

GENERAL DISCUSSION OF GROUND WATER

Almost all the water recovered from beneath the earth's surface for both domestic and industrial uses is meteoric water, that is, water derived from the atmosphere. Most of this water reaches the surface as rain or snow. Part of it is carried off by streams; part evaporates either directly from the surface and from the upper

mantle of the soil or indirectly through transpiration of plants; the remainder infiltrates into the ground to be added to the ground-water supplies.

The proportion of the total precipitation that infiltrates from the surface into the zone of saturation will depend upon the surface topography and the type of soil or surface rock. More water will be absorbed in sandy or gravelly areas, for example, than in those covered with clay. Surface run-off will be greater in hilly areas than in those that are relatively flat. In sandy regions where relief is great, the first precipitation is absorbed and run-off only commences after continuous heavy rains. Light rains falling upon the surface of the earth during the growing season may be wholly absorbed by growing plants. The quantity of moisture lost through direct evaporation depends largely upon temperature, wind, and humidity. Ground water in areas overlain by pervious material may be recharged by influent streams carrying run-off from areas overlain by relatively impervious material.

Because of the large consumption of ground water in settled areas, it may seem surprising that precipitation can furnish and adequate supply. However, when it is borne in mind that a layer of water 1 inch deep over an area of 1 square mile amounts to approximately 14,520,000 imperial gallons, and that the annual precipitation in this region, for example, is about 30 inches, it will be seen that each year some 435,600,000 imperial gallons of water falls on each square mile. Although it would be impossible to determine the annual recharge of the ground-water supply of the area, if it were assumed that only 10 per cent of the total precipitation, namely 43,560,000 gallons, is contributed to the zone of saturation, it will be seen that the annual recharge for the entire area would be a very large volume. The annual consumption

of water in all areas investigated is not known, but an estimate for some restricted areas, based on per capita consumption, shows it to be only about one-tenth of the annual recharge as estimated above.

In most regions of the world where precipitation is effective there is an underground horizon known as the ground-water level or water-table, which is the upper surface of the zone of saturation. The water-table commonly is a subdued replica of the surface topography. The water that enters from the surface into the unconsolidated deposits and rocks of the earth is drawn down by gravity to where it reaches the zone of saturation or comes in contact with a relatively impervious layer. Such a layer may stop further downward percolation, resulting in perched water and creating a perched water-table. If a water-table is at or near the surface, there will be a lake or swamp; if it is cut by a valley, there will be a stream in the valley. The terms influent and effluent are used with reference to streams and their relation to the water-table. An influent stream flows above the water-table and feeds water into the zone of saturation; an effluent stream flows at or below the water-table and receives water from the zone of saturation. An effluent stream may become influent and eventually dry up if the water-table is lowered sufficiently. The ground water in the zone of saturation is almost constantly on the move percolating towards some point of discharge, which may be a spring or a pumping well.

All rocks and soils are to some degree porous, that is, the individual grains or particles of which they are composed are partly surrounded by minute interstices or open spaces that form the receptacles and conduits of ground water. In most rocks and soils the interstices are connected and large enough for the water to move from one opening to another. In some rocks or soils, however, they are largely isolated or too small to allow movement of water. The

porosity of a material varies directly with the size and number of its interstices, which in turn depend chiefly upon the size, shape, arrangement, and degree of assortment of the constituent particles. Horizons within the earth's crust of fine-grained rock such as shale, limestone or dolomite, or unconsolidated clay or silt, may have such small interstices that the contained water will not flow readily and wells penetrating them may derive little or no water from them. Such horizons are considered impervious. Beds of more coarse-grained materials such as sand, gravel, or sandstone have greater porosity and readily yield their waters to wells. They are called water-bearing beds or aquifers. A clean water-bearing gravel is one of the best sources of water. This is true whether the water is derived from the zone of saturation or from a bed of gravel confined above, between, or below beds of less pervious material.

Consolidated rocks usually considered to be impervious may sometimes produce water in relatively good supply from openings within them of primary or secondary origin. Those of primary origin, original interstices, were created when the rocks came into existence as a result of the processes by which they were formed; e.g. bedding planes, and intergranular spaces. Secondary interstices comprise joints and other fracture openings, solution openings, and openings produced by several processes of minor importance, such as the work of plants and animals, mechanical erosion, and recrystallization; all of these involve movement of a type that acted after the consolidation of the rock. The most important interstices with respect to water supplies are the original interstices, next to them are the fracture and solution openings.

The most common wells and those that in drift-covered areas yield the largest aggregate supply of ground water are water-table wells. These are wells that derive their water from the zone of

saturation. Many shallow wells become dry during the late summer and winter, or during periods of extreme drought. In most cases this is due to the lowering of the water-table below the bottom of the well. The grouping together of a number of water-table wells within a limited area will also lower the yield of any one of the wells. This is especially true of water-producing formations of low permeability. When a well penetrates an aquifer confined by impervious beds, water will be forced upward by hydrostatic pressure exerted at the point where the well enters the aquifer. If the hydrostatic pressure is great enough to force the water to or above the surface, a flowing well is formed.

Springs are formed where the water-table, or some water-bearing aquifer, outcrops at the surface of the ground. The water emerging from water-table springs is free-running water flowing down the gradient of the water-table. In many cases these springs occur as slow seeps along the steeper slopes of stream valleys. A large number in one area could maintain a swamp. A group of permanent springs occurring in one area could provide sufficient water to maintain a lake or form the source of a stream.

GENERAL DISCUSSION OF GROUND-WATER ANALYSIS

The mineral content of ground water is of interest to many besides those industries seeking water of specific quality. Both the kind and quantity of mineral matter dissolved in natural water depend upon the texture and chemical composition of the rocks with which the water has been in contact. Pollution is caused by contact with organic matter or its decomposition products. Analyses of well waters for mineral content are made by the Mines Branch, Department of Mines and Technical Surveys, Ottawa.

In any given area, an attempt is made to secure samples of water representative of all major aquifers. The quantities of the

various constituents for which tests are made are given as "parts per million", which refers to the proportion by weight of each constituent in 1,000,000 parts of water.

The following mineral constituents are those commonly found in natural waters in quantities sufficient to have a practical effect on the value of the waters for ordinary uses:

Silica (SiO_2) may be derived from the solution of almost any rock-forming silicate, although its chief source is the feldspars. It is commonly determined in the analysis of water for use in steam boilers, as silica is classed as an objectionable encrustant.

Calcium (Ca). The chief source of calcium dissolved in ground water is the solution of limestone, gypsum, and dolomite. The common compounds of calcium are calcium carbonate ($CaCO_3$) and calcium sulphate ($CaSO_4$), neither of which has injurious effects upon the consumer, but both of which cause hardness and, the former, boiler scale.

Magnesium (Mg). The chief source of magnesium in ground water is dolomite, a carbonate of calcium and magnesium. The sulphate of magnesium ($MgSO_4$) combines with water to form Epsom-salts ($MgSO_4 \cdot 7H_2O$), and renders the water unwholesome if present in large amounts.

Sodium (Na) is found in all natural waters in various combinations, though its salts constitute only a small part of the total dissolved mineral matter in most waters in humid regions. Sodium salts may be present as a result of pollution by sewage, or of contamination by sea water either directly or by that enclosed in sediments of marine origin. Moderate quantities of these salts have little effect upon the suitability of a water for ordinary uses, but water containing sodium in excess of about 100 parts per million must be used with care in steam boilers to prevent foaming. Waters containing large quantities of sodium salts are injurious to crops and are, therefore, unfit for irrigation. The quantity of sodium salts

may be so large as to render a water unfit for nearly all uses.

Potassium (K), like sodium, is derived originally from the alkaline feldspars and micas. It is of minor significance and is sometimes included with sodium in a chemical analysis.

Iron (Fe) is almost invariably present in well waters, but rarely in large amounts. Salts, or compounds, of iron are dissolved from many rocks as well as from iron sulphide deposits with which the ground water comes in contact. It may also be dissolved from well casings, water pipes, and other fixtures in quantities large enough to be objectionable. Upon exposure of the water to the atmosphere, dissolved iron separates as the hydrated oxide that imparts a yellowish brown discoloration. Excessive iron in water causes staining on porcelain or enamelled ware and renders the water unsuitable for laundry purposes. Water is not considered drinkable if the iron content is more than 0.5 parts per million.

Sulphates (SO_4). Deposits of gypsum ($CaSO_4 \cdot 2H_2O$) are the principal source of sulphates dissolved in ground water; soluble sulphates, chiefly of magnesium and sodium, are other sources. Sulphates cause permanent hardness in water and form injurious boiler scale. Sodium and magnesium sulphates are laxative when present in quantities of more than 900 parts per million.

Chloride (Cl) is derived chiefly from organic materials or from marine rocks and sediments. It occurs usually as sodium chloride and less commonly as calcium chloride and magnesium chloride. Sodium chloride is a characteristic constituent of sewage and a locally abnormal amount suggests pollution. However, because chlorides may be derived from many sources, such abnormal quantities should not, in themselves, be taken as positive proof of pollution. Chlorides impart a salty taste to water if they are present in excess of 300 parts per million.

Nitrates (NO_3) are of minor importance in the study of ground water. Relatively large quantities in a water may represent

pollution by sewage, or drainage from barnyards, or even from fertilized fields. It is recommended that a bacteriological test be made of water showing an appreciable nitrate content if it is to be used for domestic purposes.

Carbonate (CO_3) forms a large percentage of the solid compounds held in solution by the average ground water. The two chief sources are the decomposition of feldspars and the solution of limestone by water carrying carbonic acid in solution, which is the primary agent in rock decomposition. They are indicated in the table of analyses as alkalinity. Calcium and magnesium carbonates cause hardness in water, whereas sodium carbonate causes softness.

Bicarbonate (HCO_3). Carbon dioxide dissolved in water renders the insoluble calcium and magnesium carbonates soluble as bicarbonates. Boiling reverses the process by changing the bicarbonates into insoluble carbonates, which form a coating on the sides of cooking utensils.

Total Dissolved Solids (Residue on Evaporation). The term is applied to the residue obtained when a sample of water is evaporated to dryness. Waters are considered high in dissolved mineral solids when they contain more than 500 parts per million, but may be accepted for domestic use up to that point if no better supply is available. Residents, accustomed to the waters, may use waters that carry well over 1,000 parts per million of total dissolved solids without inconvenience, although persons not used to such highly mineralized waters would find them objectionable.

Hardness is a condition imparted to waters chiefly by dissolved calcium and magnesium compounds. It here refers to the soap-destroying power of water, that is, the power of the water

first to use a certain amount of soap to precipitate the above compoun s before a lather is produced. The hardness of water in its original state is its total hardness. Permanent hardness remains after the water has been boiled, and is caused by mineral salts that cannot be removed from solution by boiling. It can be reduced by treating the water with natural softeners, such as ammonia or sodium carbonate, or with many manufactured softeners. Temporary hardness can be eliminated by boiling, and is due to the presence of bicarbonates of calcium and magnesium. Waters containing larger quantities of sodium carbonate than of calcium and magnesium compounds are soft, but if the latter compounds are more abundant the water is hard. The following table[1] may be used to indicate the degree of hardness of a water:

Total Hardness

Parts per million	Character
0-50	Very soft
50-100	Moderately soft
100-150	Slightly hard
150-200	Moderately hard
200-300	Hard
300 and over	Very hard

1 Thresh, J. C., and Beale, J. F.; The Examination of Waters and Water Supplies, p. 21, London, 1925.

Part II

MATILDA TOWNSHIP, DUNDAS COUNTY, ONTARIO

Physical Features

Matilda township is in the southwest part of Dundas county and has an area of approximately 106 square miles. The township extends along the northwest side of the St. Lawrence River from a point $2\frac{1}{2}$ miles east of the village of Cardinal to $1\frac{3}{4}$ miles west of Morrisburg. The village of Iroquois, the largest community within the township, lies about 111 miles west of the city of Montreal.

The most distinctive topographic feature of Matilda township is the wide, flat, clay-sand plain that occupies the north, west, and central parts of the township and extends in some localities into the east part. A number of small, clay till drumlins, projecting through the sand and clay, provide the only relief in this part of the area. The elevation of the plain is approximately 250 feet. In the area adjacent to the St. Lawrence River and in the east part of the township, where clay till occurs on the surface, the topography is more rolling and hilly. The relief of the entire township is less than 50 feet. Bedrock, which consists of flat-lying Ordovician sedimentary formations, outcrops only in the southwest corner of the township, and does not appear to exert any great influence on the topography. A poorly marked divide between the basins of the Ottawa and St. Lawrence Rivers crosses the south part of the township in an east-west direction. North of Iroquois, the divide is only 2 miles from the St. Lawrence River whereas at the east boundary of the township it is approximately 3 miles. The general trend of the topography in the township is approximately south 15 degrees west.

The large area north of the divide is drained by numerous small tributaries of South Nation River, a small section of which appears in the extreme northwest corner of the township. The direction of flow of these small streams, which is controlled by the trend of the topography, is in a general northeasterly direction.

A graph has been prepared depicting the monthly precipitation from 1947 to the end of 1950 as measured at various meteorological stations in the area about Matilda township and the fluctuations in the water-table as measured at an observation well near the town of Morrisburg. The latter were provided through the courtesy of the Ontario Department of Mines.

From the graph, it will be noted that, during the months when the ground is not frozen the elevations of the water-table depend, to a large extent, upon the amount of precipitation falling upon the area. In general, the lowest amount of precipitation occurs during the months of August and September, and it is during this time that the water-table shows a steady decline, reaching its lowest point commonly in the month of October.

In the subsequent months, there are periods of considerable precipitation. However, because of the frozen condition of the ground, preventing downward percolation of water, along with the fact that much of the precipitation is in the form of snow, the water-table remains low during the winter months and does not commence to rise until the end of the month of February.

The highest elevation of the water-table is commonly reached during the months of May and June. This is probably due to the supplementing of the normal precipitation with water produced by the melting of the snow and ice accumulated on the surface during the winter months.

Precipitation in inches[x]

Station	Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Brockville	1950	6.0	3.6	4.6	2.5	1.8	1.4	3.2	5.6	1.3	2.8	5.8	3.7	42.3
	1949	3.6	3.3	2.8	4.7	2.8	2.3	1.9	3.0	4.4	1.8	4.5	3.4	38.5
	1948	3.1	3.0	4.6	2.6	3.2	3.8	3.5	1.8	0.6	2.9	5.4	3.6	38.1
	1947	4.7	2.4	5.5	2.1	7.0	4.5	6.0	1.6	4.5	1.0	3.7	3.1	46.1
	1946	3.4	2.7	1.4	2.1	4.3	1.8	2.9	2.0	3.2	5.7	3.3	4.9	37.7
Domville	1950	3.8	3.2	3.7	2.7	2.0	1.1	4.3	4.1	-	1.8	4.5	3.1	-
	1949	2.6	3.3	2.6	5.0	2.2	1.2	2.2	3.4	3.3	1.7	3.3	3.3	34.1
	1948	-	-	-	-	2.7	2.9	3.5	2.3	0.2	2.7	4.2	2.8	-
	1947	-	-	-	-	-	-	-	-	-	-	-	-	-
	1946	-	-	-	-	-	-	-	-	-	-	-	-	-
Kemptville	1950	3.8	3.6	3.6	3.0	1.8	1.3	3.0	3.9	1.0	1.9	4.4	2.6	33.9
	1949	3.2	3.0	2.1	4.6	2.8	0.6	2.2	4.8	3.2	1.7	3.5	2.4	34.6
	1948	1.4	2.1	3.3	2.1	2.9	3.1	3.4	2.9	0.6	2.9	4.1	3.5	32.3
	1947	3.6	1.7	5.5	1.9	4.0	3.4	7.4	2.3	5.2	0.3	2.7	1.5	39.5
	1946	2.9	1.5	1.2	2.3	3.8	1.6	2.0	1.6	2.7	5.0	3.5	3.8	31.9
Morrisburg	1950	4.5	3.7	3.8	2.8	1.3	1.8	4.9	5.1	1.4	2.0	5.9	4.4	41.6
	1949	3.2	4.0	2.6	4.2	2.6	0.8	1.9	1.9	5.0	2.0	3.7	3.1	35.0
	1948	1.6	3.3	3.8	2.4	2.8	3.5	3.1	3.6	0.1	3.0	5.1	3.6	35.9
	1947	5.3	3.0	5.9	2.1	5.6	5.8	7.7	1.6	5.8	0.6	3.7	3.0	50.1
	1946	3.0	2.0	1.8	2.6	4.6	1.6	1.5	1.5	4.5	6.4	3.8	4.3	37.6

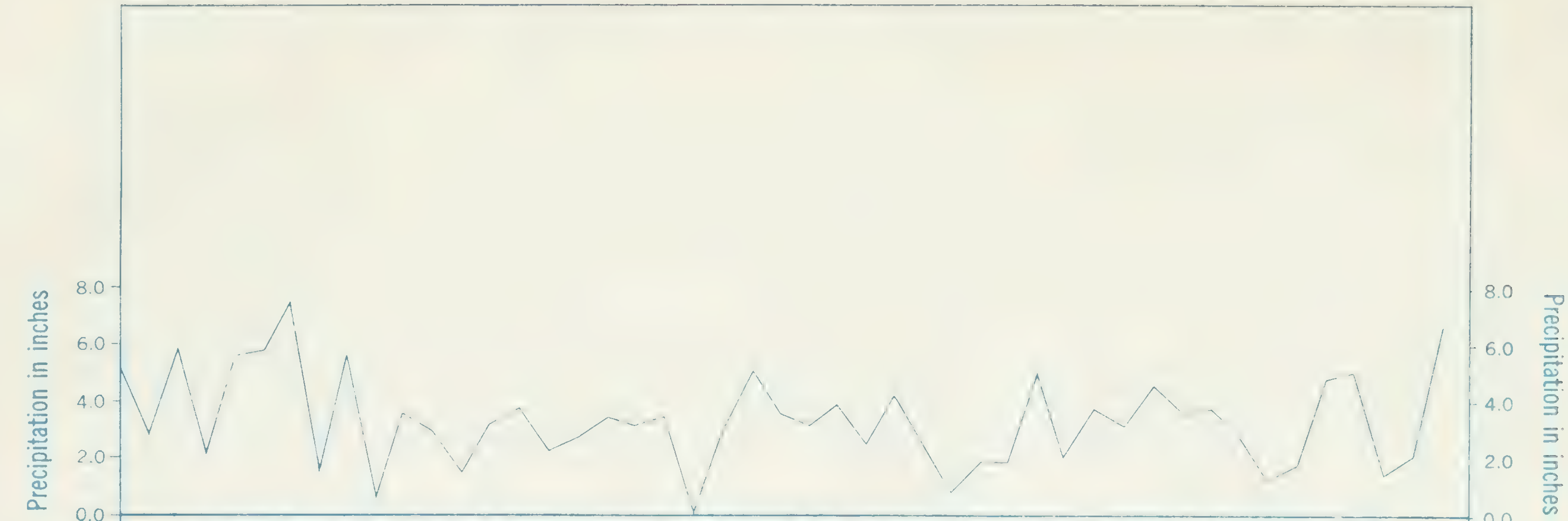
[x] Extracts from the 'Monthly Weather Map', Meteorological Service, Dominion of Canada.

WATER-TABLE ELEVATIONS

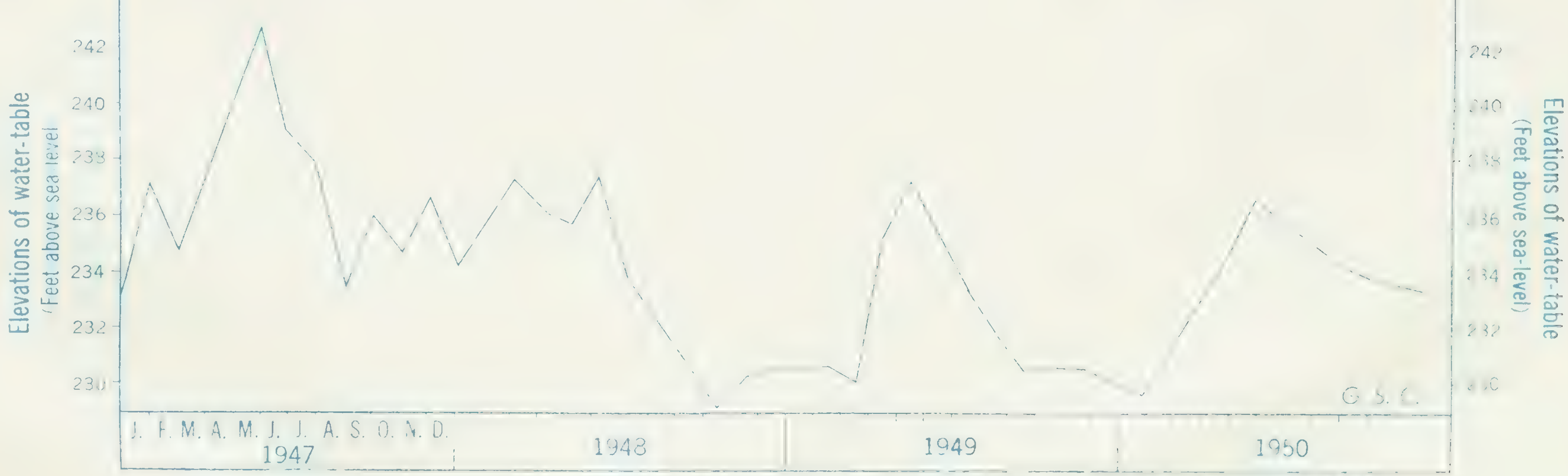
Name: W. T. Richardson
Aacress: R.R.-1 Morrisburg, Ontario
Well type: dug
Well depth: 25 feet (Aug. 22, 1950)
Well elevation: 248.0 feet above sea-level
Material from which ground water aerived: clay till

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1947	235.4	237.2	234.9	237.4	240.1	242.8	239.0	237.9	233.7	236.1	234.9	236.8
1948	234.3		237.4	236.4	235.7	237.5	233.8		230.9	229.2	230.3	230.6
1949	230.6	230.7	230.1	235.3	237.4	235.3	233.4	231.9	230.5	230.7	230.5	229.6
1950				234.7	236.7			234.3	233.9		233.4	

Fluctuations of water-table, courtesy of the Ont. Dept. of Mines



Graph depicting amount of precipitation in Morrisburg area. Ontario, from January 1947 to December 1950.



Graph depicting fluctuations in water-table in Morrisburg area, Ontario from January 1947 to December 1950
(Courtesy of the Ontario Department of Mines)

Geology

Bedrock Formations. The township, which is located within the Ottawa-St. Lawrence Lowland, is underlain by Palaeozoic rocks of Ordovician age. These sedimentary formations are located on the west flank of a broad, synclinal structure that extends northeast across the counties of Dundas, Stormont, and Glengarry. The dip of the rocks underlying the township is extremely low and in a general northeast direction.

Table of Formations[1]

Era	Period	Sub Epoch	Formations	Thickness (Feet)	Lithology
Palaeozoic	Ordovician	Trenton and Black River	Ottawa	690-700	Limestone with a little shale and some sand at its base
		Disconformity			
		Chazy	St. Martin Rockcliffe	20-155 150-165	Impure limestone Shale with sandstone lenses
		Disconformity			
		Beekmantown	Oxford	240 (±)	Dolomite with a little shale at the top
			March	30 (+)	Interbedded sandstone and dolomite
	Ordovician or Cambrian		Nepean	up to 500	Sandstone
Great unconformity					
Precambrian (Archaean)?			Grenville		Crystalline limestone, quartzites and metamorphic rocks; associated granite, and granite-gneiss

[1] Wilson, A. E.: Geology of the Ottawa-St. Lawrence Lowland, Ontario and Quebec; Geol. Surv., Canada, Memoir 241, p. 9, (1946).

Matilda township is underlain by several formations, four of which come to the surface or directly underlie the drift in certain parts. The Oxford directly underlies the southwest part as well as a small area in the extreme northwest corner of the township. The succeeding Rockcliffe and St. Martin formations underlie broad, curving areas extending across the centre of the township from the north boundary to the St. Lawrence River. The Ottawa formation underlies the northeast part of the township. A number of small outcrops of the Oxford formation occur in the southwest part of the township between Iroquois and the west boundary.

Unconsolidated Deposits. The types of unconsolidated deposits occurring in the township, classified according to their origin and arranged in order of their deposition from oldest to youngest, are as follows: glacial, glacio-fluvial, and marine deposits. Recent deposits are relatively scarce and unimportant.

The glacial deposits that overlie bedrock throughout a large part of the township occur chiefly as ground moraine. Altogether, they are exposed for approximately 32 square miles, principally in the southeast part and along the east boundary of the township. Elsewhere they are buried beneath glacio-fluvial and marine deposits and are only encountered during drilling or excavating operations. In some localities in the north part of the township, they project above the surrounding flat plain as elongated hills and ridges of clay till. Many of these structures appear to be the upper parts of half-buried drumlins with their long axes parallel to the direction of the last ice movement. Some have the appearance of "islands" of clay till in a "sea" of marine sand and clay. Thin layers of till, reworked by the invading marine waters of the Champlain Sea, and thicker deposits of marine sand and gravel occur on the northwest flanks and tops of some of the higher ridges. They are frequently

associated with accumulations of large boulders.

Glacio-fluvial deposits, in the form of kames, occur in the northwest corner of the township. They are continuous with larger deposits farther west in Edwardsburg township. The relief of these deposits has been considerably lowered by the planing action of waves so that at the present time they occur as low, scattered knolls and ridges of sand and fine gravel.

Although no outwash deposits of sand and gravel were observed on the surface of the township, the owners of a large number of wells drilled to bedrock, located in the north and central parts of township, reported beds of gravel, 2 to 6 feet thick, beneath marine clay and sand, and directly overlying bedrock. The fact that a number of wells drilled in the same area did not encounter the gravel suggests that, although the gravel beds are probably extensive, they are not continuous throughout the entire township.

The invasion and subsequent withdrawal of the Champlain Sea, which followed the retreat of the ice-sheet in the region, formed varied deposits of marine origin. The most extensive of these in Matilda township are deposits of marine clay and sand, which cover approximately two-thirds of the township and are located principally in the north, west, and central parts. Marine clay deposits extend over a large part of the township. Much of the clay is covered with a thin layer of marine sand, but a wide belt of the material is exposed extending from a point 3 miles south of the community of Brinston to the north boundary of the township. The area about Brinston, which is located near the centre of the marine clay area, has been aptly called the "Brinston Flats". Except for the above, and a few isolated areas in the south part of the township, marine clay can only be seen along the banks and in the bottoms of small creeks.

A thin layer of marine sand, varying from a few inches to a few feet in thickness, covers the west part of the township. This layer

is continuous with thicker deposits farther west in Edwardsburg township. In most instances it overlies marine clay or clay till.

Recent deposits, such as alluvium, are rare in the township and are not considered to be of importance.

Variations in the thickness of the drift throughout the township were determined in many localities from the data compiled from a number of wells that were reported to have reached bedrock. The following table indicates the minimum and maximum thicknesses of drift where it could be determined in this way:

Concession	Lot	Minimum and maximum thickness of drift (Feet)	Concession	Lot	Minimum and maximum thickness of drift (Feet)
1	1	46- ?	2	23	33- ?
1	4	30- ?	2	26	37- ?
1	7	29- ?	2	29	36*-?
1	10	34- ?	2	32	56*-?
1	13	31- ?	2	35	19- ?
1	16	44- ?	2	38	41*-50*
1	19	18- ?	3	3	23- ?
1	22	26- ?	3	6	33- ?
1	25	25- ?	3	9	40*-?
1	28	53- ?	3	12	25- ?
1	31	37- ?	3	15	38- ?
1	34	30- ?	3	21	31- ?
1	37	10*-29	3	24	44*- ?
2	2	65*-?	3	27	28- ?
2	5	46*?	3	30	35*-?
2	8	60*-?	3	33	13-?
2	11	38- ?	4	1	21- ?
2	14	39- ?	4	4	25*-?
2	17	26- ?	4	7	36*-?
2	20	60*-?			

Concession	Lot	Minimum and maximum thickness of drift (Feet)	Concession	Lot	Minimum and maximum thickness of drift (Feet)
4	10	42- ?	6	15	18*-19*
4	13	39- ?	6	18	21- ?
4	16	24- ?	6	21	30- ?
4	19	40*-?	6	24	15- ?
4	22	23- ?	6	27	20- ?
4	25	58*-59*	6	30	32- ?
4	28	50*-?	6	33	23*-?
4	31	24*-?	6	36	13- ?
4	34	11- ?	7	7	31*-37*
4	37	22- ?	7	10	5*- 12*
5	5	33- ?	7	13	13- ?
5	5	14- ?	7	16	12- ?
5	8	32*-39*	7	19	17- ?
5	11	22- ?	7	22	26- ?
5	14	36- ?	7	25	24- ?
5	17	36- ?	7	28	22- ?
5	20	31- ?	7	31	34*-37*
5	23	16-?	7	34	40*-?
5	26	42*-?	7	37	20*-?
5	29	24- ?	8	14	21- ?
5	32	19- ?	8	17	12-13
5	35	21- ?	8	20	17*-?
5	38	25- ?	8	26	20- ?
6	6	3*-22*	8	29	12*-24*
6	9	16*-30*	8	32	25*-?
6	12	21*-?	8	35	17*-19*

* To bedrock.

WATER SUPPLY

Because of the great areal extent of marine clay and clay till deposits, which in many cases do not yield satisfactory supplies of ground water, Matilda township is not as well supplied with water as the adjacent townships of Edwardsburg and Williamsburg. About 77.8 per cent of the wells are of the dug type, and 22.2 per cent were drilled, chiefly into bedrock. Approximately 80.1 per cent are obtaining their water from depths of 40 feet or less. A compilation of the well records shows that about 86.6 per cent of the wells have a permanent water supply sufficient for the present demands made upon them, and 12.6 per cent constitute wells that go dry intermittently. In describing the principal beds that yield water to the wells, the statements of owners and drillers as to the character of the aquifer were necessarily accepted.

Clay till in the township is not a good source of water. Commonly it constitutes a poor reservoir for ground-water storage as it takes up water slowly and holds relatively little. Furthermore, the slow circulation generally results in the quality of ground water obtained being poor. Many shallow wells dug in clay till are reported as being intermittent or low in summer, the reason being the low permeability of clay till that causes it to yield water slowly to wells. Consequently, a well in it can be easily pumped dry and takes a long time to recover. In later summer, when the water-table is low, the deceased area yielding water directly to the well renders the supply even more unsatisfactory. To overcome this difficulty, the owner should dig his well as deep as possible to form a reservoir large enough to provide sufficient water during times when large amounts are being withdrawn from the well.

A large number of wells, 12 to 38 feet deep, dug in clay till along highway No. 2, west of Iroquois, appear to yield sufficient quantities of ground water. This may result from the percolating of ground water

down the hydraulic gradient south from the divide to the St. Lawrence River. It was reported that, when dug, a number of these wells encountered "springs" in the bottom of the well. The water was not under hydrostatic pressure although it flowed freely into the well during pumping operations. It is doubtful if the material yielding water at the bottom of these wells is clay till, but rather consists of a lens or pocket of sand and gravel, many of which are reported to be scattered throughout the till. The quantity of water yielded by these more porous materials would depend upon their relative extent. It is thought that the majority of these deposits draw their water from the confining till, and, accordingly, the chief result of their presence is to cause a greater area of till to yield its water to the well. In some instances, these wells yielded large quantities of water when first dug, but after a period of time had elapsed assumed the properties of wells deriving their entire supply of ground water from clay till, often going dry during the late summer or extended periods of drought and yielding only limited supplies during normal times.

Wells dug in clay till located along highway No. 2 east of Iroquois vary in depth from 20 to 40 feet, with an average of 28 feet. Approximately half of these wells are reported low in summer and one-third are intermittent. The average depths of wells dug in clay till along highway No. 2 west of Iroquois are as follows: sufficient supply, 29 feet; not used, 28 feet; low in summer, 26 feet; intermittent, 23.5 feet. From the above figures, it would appear that the most satisfactory wells are those that are 29 feet or more in depth.

There are many intermittent wells located along the road between cons. I and II extending from lots 18 to 24. In most instances these wells are not sufficiently deep. A well dug in clay till in this area must be at least 30 feet deep to yield satisfactory supplies of ground water. The supply of wells located immediately south of the ridge crossing the road approximately one mile south of Irena is more satisfactory, but a 40-foot well located on top of the same ridge is reported to be intermittent,

This would suggest that the water-table lies at greater depths beneath rises in topography than in more level areas.

The average depths of wells dug in clay till along the road between cons. II and III, lots 1 to 14, are as follows: sufficient supply, 30 feet; low in summer, 29 feet; not used, 22 feet; and intermittent, 19 feet; and further north, in cons. IV and V, the average depths are: sufficient supply, 25.5 feet; low in summer, 25 feet; not used, 18 feet; intermittent, 14 feet. These figures indicate the necessity of deepening the intermittent wells if they are to provide sufficient quantities of ground water.

Wells dug in the clay till ridge extending northeast from Toyehill, lots 1 to 6, cons. VII and VIII, range from 17 to 34 feet in depth and are all reported to yield sufficient supplies of ground water for farm use. Most wells dug in the clay till ridges, which are scattered throughout the flat clay-sand areas in the north and west parts of township, should attain a minimum depth of 37 feet to be satisfactory. A number of the more shallow wells are reported to be intermittent. In the area 1 mile to 2 miles west of Irena, wells dug 16 to 25 feet in the flat sand areas are satisfactory, whereas in the higher clay till areas, wells dug as deep as 45 feet are reported to yield only fair supplies of ground water. The deepest dug well in the township, located in lot 3, con. II, is dug 61 feet in clay till and is reported to yield a satisfactory supply of water.

Ground water under hydrostatic pressure is seldom yielded directly by clay till. In most instances, the wells are non-artesian and are deriving their water from the zone of saturation below the water-table. Wells in areas in which clay till has been reworked are more satisfactory than in those areas where it has not. This is due to the greater permeability of the reworked material, which has had a large quantity of the finer

particles washed from it.

The supply of ground water yielded by the kame deposits located in the northwest corner of the township is reported to be satisfactory. The water-table in this area is relatively low and, consequently, the average depth of dug wells is greater than in other parts of the township. Clay till underlies the greater part of these kame deposits. In many places satisfactory supplies of ground water can be obtained from the sand lying immediately above the till.

A large number of wells in the marine sand and clay areas located in the north part of the township, especially in the vicinity of the community of Hulbert, are reported to have encountered beds of sand and gravel beneath the marine sediments and directly overlying bedrock. It is thought that these deposits are outwash and that they could be developed into an important source of ground water for the north and west parts of the township.

The following are logs, as supplied by well owners, of representative wells that encountered sand and gravel below marine clay.

Lot. 22, con. V

Feet	
0 to 55	- clay
55 to 56	- gravel
at 56	- bedrock

Lot 23, con. VI

Feet	
0 to 34	- clay
at 34	- gravel

Lot. 26, con. VII

Feet	
0 to 2	- sand
2 to 39	- clay
39 to 42	- gravel
at 42	- bedrock

Wells in lot 32, con. VI, lot 30, con. VII, and lots 33 and 34, con. VII, are also reported to be deriving their water from gravel deposits encountered below varied thicknesses of marine clay.

However, a number of wells drilled to bedrock in the same general area did not encounter gravel. This would suggest that the outwash deposits do not occur as a continuous sheet throughout the entire area but rather as scattered deposits possibly filling the lower areas in bedrock. The water encountered in the outwash materials, or "water-gravels" as they are referred to locally, is usually under considerable hydrostatic pressure and rises to within a few feet of surface. The fact that the "water-gravels" are capable of yielding large supplies of ground water is evident from the reports of various well owners who state that continuous pumping fails to lower the static level of the water in their wells. The 63-foot well drilled at the cheese factory at Hulbert, lot. 18, con. VIII, obtains up to 3,000 gallons of water a day from the "water-gravel" without lowering the level of the water in the well. A 50-foot well, drilled in lot 34, con. VI, which is reported to be obtaining its water from gravel below clay, flows slowly during the period November to July.

Deposits of marine clay that cover the north-central part of the township and underlie a large part of the marine sand areas yield various quantities of ground water to many wells. The problems encountered in attempting to obtain satisfactory supplies of ground water from marine clay are comparable with those in clay till areas. Marine clay is too dense to yield its water content readily, and wells dug in this material necessarily have to go a considerable distance below the water-table in order to provide a reservoir large enough to yield a satisfactory supply of water. Most wells dug in marine clay that are reported to be unsatisfactory, are so not because of the lowering of water-table but because of the poor permeability of the material.

In most cases, due to this extremely poor permeability, a well could be dug in clay a considerable distance below the water-table before

there would be any evidence of free water in the well. It is suggested that the only method to accurately determine the location of the water-table in clay is by making laboratory tests to determine if the material is saturated. A well dug in clay would necessarily have to remain in disuse for a considerable length of time before the elevation of the surface of the free water would approach that of the water-table.

Although it is a more laborious task to dig a well in heavy marine clay than in sand or gravel, it is easier to penetrate the zone of saturation below the water-table and thus create a larger reservoir. In some wells, the marine clay was found to be so firm and compact that lining the well with rock or wooden cribbing was not considered necessary. It is doubtful, however, if wells such as these would be as satisfactory as those that have been properly lined.

When ground-water data were being gathered in the township (July 1950) the water-table in the marine clay areas appeared to be fairly high; in most places the surface of the water in the wells was from 4 to 6 feet below the ground surface. Most wells dug in the marine clay area were deep enough to contain sufficient water for ordinary farm needs. However, it was reported that some of the wells could be pumped dry, and took an extremely long time to recover. One such well, dug 20 feet in clay, occurs in lot 31, con. VII. This well should be deepened. A number of other wells in the marine clay area are not in use, which is usually a good indication that they do not yield a satisfactory supply of ground water. In the vicinity of Haddo, lots 28 to 34, cons. II and III, the marine sand overlying clay is very thin and all the water derived by dug wells is from the clay. The wells in this area, from 20 to 38 feet deep, are mostly satisfactory and provide sufficient water for normal uses. Wells of less depth are not satisfactory and should be deepened to provide a larger reservoir for the ground water. Wells from 9 to

15 feet deep, dug in clay, in lot 27, con. VI, are reported to be unsatisfactory, whereas a 39-foot well, in lot 32, con. V, is reported to yield excellent supplies of ground water. A well at Dixons Corners (No. 7 on the compilation sheet), dug 16 feet in clay, is reported to supply sufficient water for several families.

The marine sand deposits, which extend along the west part of the township, are exceedingly thin and are not considered a good source of ground water. Wells dug in this area usually obtain their water from the underlying marine clay, which is the predominant material underlying the sand, or from clay till or bedrock. Precipitation falling upon sandy areas rapidly sinks in and percolates downward until it reaches the more impervious marine clay or clay till. These materials slow the downward movement of the water to such an extent that the sand immediately above frequently becomes saturated with water, forming a perched water-table. A few wells dug down through the sand to the more impervious material are reported to have encountered "springs" in the bottom of the well. This is merely ground water seeping rapidly into the well from the porous, saturated sand. It is difficult to determine if the water in wells dug through sand into the underlying clay is perched or not because the great permeability of the sand permits surface water to pass through it and fill the well rapidly to the level of the water in the perched water-table.

So far as is known, there are no wells in the township deriving their water from alluvial deposits.

Altogether, some 214 wells have been drilled into bedrock in the township, and all are reported to be deriving at least part of their ground water from that source. The depths of the wells range from 15 197 feet with an average of 70.9 feet.

A compilation of data from wells reported drilled to bedrock

in Matilda township, exclusive of communities, and arranged according to the formation from which the water is considered to be derived, is as follows:

Formation	Number of Wells	Classification				Depths of wells (feet)			Depths to water (feet)			Quality		
		F.A.	N.F.A.	N.A.	I.W.	Min.	Max.	Ave.	Min.	Max.	Ave.	Hd.	Sft.	Sul.
Ottawa	53	0	13	39	1	15	127	70.0	3	19	7.6	53	0	0
St. Martin	47	0	33	14	0	33	183	79.1	2	23	10.0	39	5	3
Rockcliffe	84	2	47	34	1	21	197	69.4	0	53	9.4	79	2	2
Oxford	25	0	6	14	5		180	68.4	3	21	11.7	25	0	0
Total	209	2	99	101	7							196	7	5

The Oxford formation, which consists of grey limestone, magnesium limestone, and dolomite, is not considered an important source of ground water within Matilda township. Altogether some 25 wells are reported to be deriving their water from this source, of which 5 are intermittent and only 6 encountered water under pressure. The Oxford appears to be less satisfactory as a source of ground water when it occurs relatively close to surface. Seven wells deriving their water from the Oxford occur in a small area approximately 1 mile northwest of Iroquois, where bedrock is overlain by 11 to 18 feet of overburden. Of these wells, 5 are non-artesian and 2 are intermittent. Farther northwest, where bedrock exists at depths as great as 56 feet, a number of non-flowing artesian wells occur. Ground water derived from the Oxford is generally hard and clear with a low mineral content. Although it is not considered an excellent source of ground water, the Oxford formation will normally yield sufficient water to satisfy the needs of an average farm.

The Rockcliffe formation, consisting of grey-green shale with lenses of grey sandstone, constitutes the most important bedrock source of ground water in the township. Some 83 wells, of which 2 are flowing artesian and 47 non-flowing artesian, are deriving their water supply from this source. Several of the latter are reported to flow during part of each year, and in others the water levels were reported to remain constant during continuous pumping. A wide valley in bedrock, filled with from 60 to 85 feet of drift, exists between Iroquois and Rapide Plat and extends as far north as Rowena. A large number of non-flowing artesian wells deriving their ground-water supplies from the Rockcliffe occur in this area.

The flowing-artesian wells, in lot 31, con. VI, and lot 22, con. VIII, reported to be deriving their water from the Rockcliffe, are

believed to be related to a drift-filled valley in bedrock extending from a point 2 miles east of Glen Stewart northeast to Hulbert and beyond. This same valley extends southwest into the Pittston area in adjacent Edwardsburg township where several flowing-artesian wells are known to occur.

The St. Martin formation, consisting of limestone, minor shale, and dolomite, directly overlies the Rockcliffe. Although the St. Martin underlies as much of the township as the Rockcliffe, about half as many wells are reported to be deriving their water from this source. The reason appears to be that the St. Martin is overlaid by a greater thickness of overburden than the Rockcliffe, necessitating drilling deeper and more expensive wells. Approximately 70 per cent of wells drilled into the St. Martin are non-flowing artesian, indicating that the formation is an excellent source of ground water. The water from a number of wells deriving their water from the St. Martin is reported to be very hard, Approximately 6 per cent of the wells for which information has been compiled were reported to have a strong hydrogen sulphide odour. Although the latter are not satisfactory for domestic purposes, they are being used in many places for stock.

A drift-filled valley in the bedrock surface cuts across the township in a northeast direction, passing about 1 mile west of the community of Brinston. Although this buried valley is located in the St. Martin formation for a considerable distance, no flowing-artesian wells are known to occur in its vicinity.

The Ottawa formation, which consists of grey limestone, with dolomite, shale, and sandstone in the lower part, is the uppermost bedrock formation underlying the township. The water-yielding properties of the Ottawa are comparable to the Oxford formation in that less than 25 per cent of wells drilled into it are reported to be non-flowing artesian.

However, in lot 6, con. VII, a 63-foot drilled well was reported to have encountered water in the Ottawa under sufficient hydrostatic pressure to force the water to within a few feet of the surface. The water level in this particular well cannot be lowered by continued pumping.

Two wells, both drilled into the Ottawa formation, were reported to have been affected by the earthquake of 1944, which centred in the Cornwall-Massena area some 26 miles to the east. One 70-foot well, in lot 13, con. V, went dry after the earthquake, continued dry for approximately a year, and then gradually came back to its original capacity. A second, 90-foot well, in lot 4, con. VI, drilled 72 feet into the Ottawa formation, reported an increased supply of ground water following the earthquake. The Ottawa is the only bedrock formation underlying the township whose aquifers were reported to have been disturbed by the earthquake.

Community Supplies

Ground-water conditions within the following three communities in the township of Matilda were investigated: Brinston, Dixons Corners, and Dundela. Maps showing the location of all wells for which information has been obtained and indicating both topographic and water-table contours accompany this report. Although the contours are somewhat generalized they are believed to be sufficiently accurate for the purpose for which they are being used. Compilation sheets containing pertinent data concerning the individual wells in each community are attached at the back of this report. To determine the depth to water in any one place, it is necessary only to subtract the elevation of the nearest water-table contour from that of the nearest surface contour.

Community of Brinston. The water supply of this community is derived entirely from privately owned wells. There are 24 wells in the community, of which 21 are dug and 3 are of the drilled type. The

dug wells are all reported to derive their water from marine clay, whereas two of the drilled wells obtain their water supply from the underlying St. Martin formation and the third from sand underlying the marine clay.

The depths of the wells dug in marine clay vary from 8 to 23 feet, with an average of 14 feet. With the exception of three of the more shallow wells, which are intermittent, the supply of ground water yielded by marine clay is reported to be sufficient for domestic purposes. All the wells derive their water from the zone of saturation below the water-table. No ground water under hydrostatic pressure was encountered in the marine clay. It is thought that the intermittent wells should be deepened during the late summer when the water-table is at its lowest level.

It was reported that large supplies of ground water can be obtained from the underlying bedrock. Although no figures were acquired as to the maximum quantity of water that could be obtained, the well at the cheese factory was reported to yield 400 gallons a day without lowering the static level of the water in the well. The water encountered in the bedrock is under sufficient hydrostatic pressure to raise it a considerable distance in the well. Bedrock, underlying the community, is covered with approximately 30 feet of overburden.

One non-flowing artesian well is obtaining excellent supplies of ground water from sand underlying marine clay. The sand is possibly outwash material deposited immediately above bedrock during the retreat of the ice-sheet. It is not thought to be continuous over any large area and, accordingly, will not necessarily be penetrated in every well drilled to bedrock in the community.

Community of Dixons Corners. Ground-water conditions at Dixons Corners are similar to those at Brinston, as both communities are situated within the same marine, clay plain. There are 11 privately owned wells in Dixons Corners, 9 of which are dug and 2 drilled.

The dug wells, which are all reported to be obtaining their water from marine clay, vary in depth from 12 to 22 feet, with an average depth of 18 feet. The quantity of water yielded is reported to be satisfactory for domestic purposes. No intermittent wells were reported within the community.

One 45-foot drilled well that penetrated the underlying St. Martin formation at an unknown depth is reported to be obtaining excellent supplies of ground water. A second well drilled to a depth of 39 feet is obtaining water from gravel underlying marine clay. The water in both wells is under considerable hydrostatic pressure, especially in the spring, at which time the well obtaining water from gravel frequently flows at the surface.

The depth to bedrock is nowhere known exactly, but it must lie within 45 feet of the surface in the vicinity of the well reported to be obtaining its water from bedrock.

Community of Dundela. The community of Dundela is located along and across the crest of a large, clay-till drumlin striking in a general southwest direction. Information has been compiled on 14 wells in the community, 12 of which were dug and 2 drilled.

The dug wells, all of which are obtaining their ground-water supplies from clay till, vary in depth from 12 to 36 feet, with an average depth of 25 feet. It will be noted that the average depth of the dug wells at Dundela is much greater than at either Brinston or Dixons Corners. All the dug wells in the three communities are dependent upon ground water from the zone of saturation below the water-table for their water supply, and the greater depth of the wells in the till would indicate that the water-table is closer to the surface in the broad, flat, clay plain surrounding the communities of Brinston and Dixons Corners than in the higher clay-till area at Dundela. Except for one intermittent well, the quantity of water yielded by the clay till is reported to be

satisfactory for domestic purposes, and deepening this well would probably result in it producing a sufficient supply of ground water.

One well, drilled to a depth of 96 feet, was reported to have encountered bedrock at 26 feet. Although the water encountered does not appear to be under hydrostatic pressure, the well was reported to yield supplies sufficient for all normal uses. It is thought that a large percentage of the water derived from this particular well is obtained from the overlying unconsolidated material or from the contact of the unconsolidated material and bedrock.

A number of the dug wells within the community are more than 26 feet in depth. This would indicate that undulations, possibly of a minor nature, occur in the underlying bedrock surface, and, accordingly, it would not be possible to predict accurately the depth to bedrock at any one point in the community.

ANALYSES OF WATER SAMPLES

Twelve samples of well waters from Matilda township were analyzed for their mineral content in the laboratory of the Mines Branch, Department of Mines and Technical Surveys, Ottawa. The samples were taken from wells varying in depth from 16 to 100 feet, with aquifers in both drift and bedrock. Most of the ground water except for two wells where the nitrate content is abnormally high, appears to be suitable for domestic and farm use. It is suggested that bacteriological tests should be made of these well waters if they are to be used for domestic purposes. Most contamination of well waters results from surface water seeping into the well, either at surface or at the bottom of the casing or cribbing. It was noted that one well whose nitrate content was reported to be zero is of excellent construction with little chance of contamination. Water derived from the St. Martin formation appears to contain the largest amount of sulphate and chloride compounds. The chlorides, if present in excess of

300 parts per million, would render the water saline to the taste. The analyses indicate that the Ottawa formation yields the hardest water and the chemical content of the water from the Rockcliffe formation varies considerably throughout the township.

Amounts[1] of Dissolved Mineral Matter in Well Waters collected in Matilda Township

Constituent	Well waters from glacial drift and bedrock (12 samples)		
	Maximum	Average	Minimum
Residue on evaporation(105°C)	1339	681.1	324
Calcium	160.5	776.0	28.0
Magnesium	100.3	40.2	21.6
Sodium	204.0	68.5	12.0
Potassium	224.0	35.9	2.4
Sulphate	197.1	75.2	17.7
Chloride	343.0	87.1	5.4
Nitrate	248.1	51.9	0.0
Bicarbonate	517.5	331.3	235.7
Carbonate	16.8	2.9	0.0
Silica (Col.)	23.2	12.0	7.8
Total hardness	621.0	375.7	156.5

[1]In parts per million

In answer to the requests of a number of well owners, the following method is recommended when it is desired to sterilize a well[2]: Mix one heaping tablespoonful of chlorinated lime with a little water to make a thin paste, being sure to break up all lumps; stir this paste into 1 quart of water; allow the mixture to stand a short time and pour off the clear liquid. The chlorine strength of the solution is about 1 per cent: 1 quart of the liquid is enough to sterilize 800 imperial gallons of water.

[2]Well Drilling, Technical Manual, TM 5-295, United States Government Printing Office, Washington, 1943.

Estimate the volume of water in gallons standing in the well, and for each 800 imperial gallons pour 1 quart of the sterilizing solution into the well. No harm is done if too much solution is used, and it is better to use too much than too little. Agitate the water thoroughly and let it stand for several hours, preferably over night, then flush the well thoroughly to remove all of the sterilizing agent. The sides of the well above the surface of the water can be sterilized by returning the water to the well during the first part of the flushing. Just before completion of the flushing, a sample of the water may be taken if required.

To determine the amount of chlorinated lime solution that should be added to the well waters, it is necessary to know the diameter of the well and the depth of water in the well. With this knowledge, together with the information given in the table below, the volume of water present in the well can be easily calculated and the correct amount of lime solution added.

Diameter of well (feet)	Number of imperial gallons per foot depth
2.0	19.6
2.5	30.6
3.0	44.1
3.5	59.9
4.0	78.3
4.5	99.1
5.0	122.3

CONCLUSIONS

This investigation warrants the following conclusions:

1. Ground-water resources in Matilda township, though not abundant, are adequate for domestic, stock, and community purposes.
2. To ensure a satisfactory supply of ground water, wells dug in clay-till areas should be a minimum of 35 feet in depth. Wells of less depth often become intermittent during the late summer or early autumn.
3. Wells in marine clay should be dug to a minimum depth of 28 feet to ensure a supply of ground water sufficient for domestic or farm use.
4. Outwash deposits of sand and gravel located between the marine clay deposits and underlying bedrock in the north part of the township might possibly be developed into an important source of ground water.
5. The Oxford formation constitutes a fair source of ground water within the township. Although there is only a limited number of non-flowing artesian wells in the Oxford, the water is mostly hard and clear with small amounts of total dissolved solids.
6. The Rockcliffe formation constitutes the most important single source of ground water in the bedrock underlying the township. Over half of the wells deriving their water from the Rockcliffe are non-flowing artesian and 2 flowing-artesian wells obtain their water from this source.
7. The supply of ground water that can be derived from the St. Martin formation is large. However, the presence of hydrogen sulphide in a number of the wells prevents some of the water from being used for domestic purposes. It is, however, satisfactory for stock.
8. Although some wells encountered ground water under considerable hydrostatic pressure in the Ottawa formation, most wells obtaining water from this source are non-artesian. The quality of the water

is comparable with that of the Oxford formation. It is hard and and clear and relatively low in total dissolved solids.

9. Flowing-artesian wells in the township appear to be related to a drift-filled pre-glacial valley in bedrock. This valley extends southwest from Matilda township into the Pittston area in adjacent Edwardsburgh township, where several flowing-artesian wells are known to occur.

10. The best supplies of ground water for the community of Brinston will be obtained from bedrock, which occurs about 30 feet below surface. Wells dug into marine clay to a depth of 15 feet or less are seldom satisfactory.

11. Although the marine clay covering the adjoining areas appears, in most instances, to be a satisfactory source of ground water, the best supplies of ground water in the community of Dixons Corners will be obtained by drilling through the clay into bedrock, which exists approximately 45 feet below the surface.

12. Although it is necessary to dig the wells considerably deeper in Dundela than in Dixons Corners or Brinston, the quantity of ground water yielded by the clay till is sufficient for normal domestic purposes. Bedrock of the Ottawa formation, at approximately 26 feet below the surface of ground, is capable of yielding large quantities of ground water.

Matilda Twp.

Summary of wells and springs used as a source of Water Supply, exclusive of Communities

Wells and springs	Concessions I	II	III	IV	V	VI	VII	VIII	Total number in township	Per cent of total
Total number	215	154	128	145	160	157	126	132	1217	
Dug	187	128	112	118	116	106	89	92	945	77.8
Bored	0	0	0	0	0	0	0	0	0	0
Drilled	35	26	16	25	44	50	37	40	272	22.2
Feet deep										
Wells 0-20	73	47	44	68	67	69	62	55	485	39.9
21-40	114	68	64	49	69	46	34	46	488	40.2
41-60	14	14	6	14	6	16	14	12	96	7.9
61-80	8	7	2	3	10	8	6	6	46	3.8
81-100	2	5	2	3	10	12	5	6	45	3.8
Over 100	2	7	3	2	2	2	0	5	23	1.9
Depth unknown	2	6	7	6		6	5	2	34	2.8
Wells that yield hard water	214	154	128	141	156	149	126	128	1199	98.5
soft water	1	0	0	4	4	4	0	4	18	1.5
salty water	0	0	0	0	0	0	0	0	0	0
Wells with aquifer in clay	17	26	24	40	59	49	62	65	342	28.40
in sand	21	11	18	15	3	6	5	14	93	7.50
in gravel	29	10	6	14	5	11	8	11	94	7.51
in clay till	121	81	69	55	64	40	23	10	463	38.0
In bedrock	27	26	11	18	24	45	25	32	209	17.2
Unknown	0			3	2	3	0	0	8	.66
Well types: flowing artesian	0	0	0	0	0	1	0	1	2	.16
Non-flowing artesian	17	12	9	18	10	18	19	16	119	9.82
Non-artesian	160	103	83	108	143	127	98	107	934	76.60
Intermittent	36	34	35	19	5	8	9	7	153	12.60
Dry holes	0	0	1	0	2	1	0	1	5	9.41
Not used	22	40	22	22	36	36	37	22	237	19.5
Springs	2	0	0	0	0	0	0	0	2	.16

Matilda Twp.

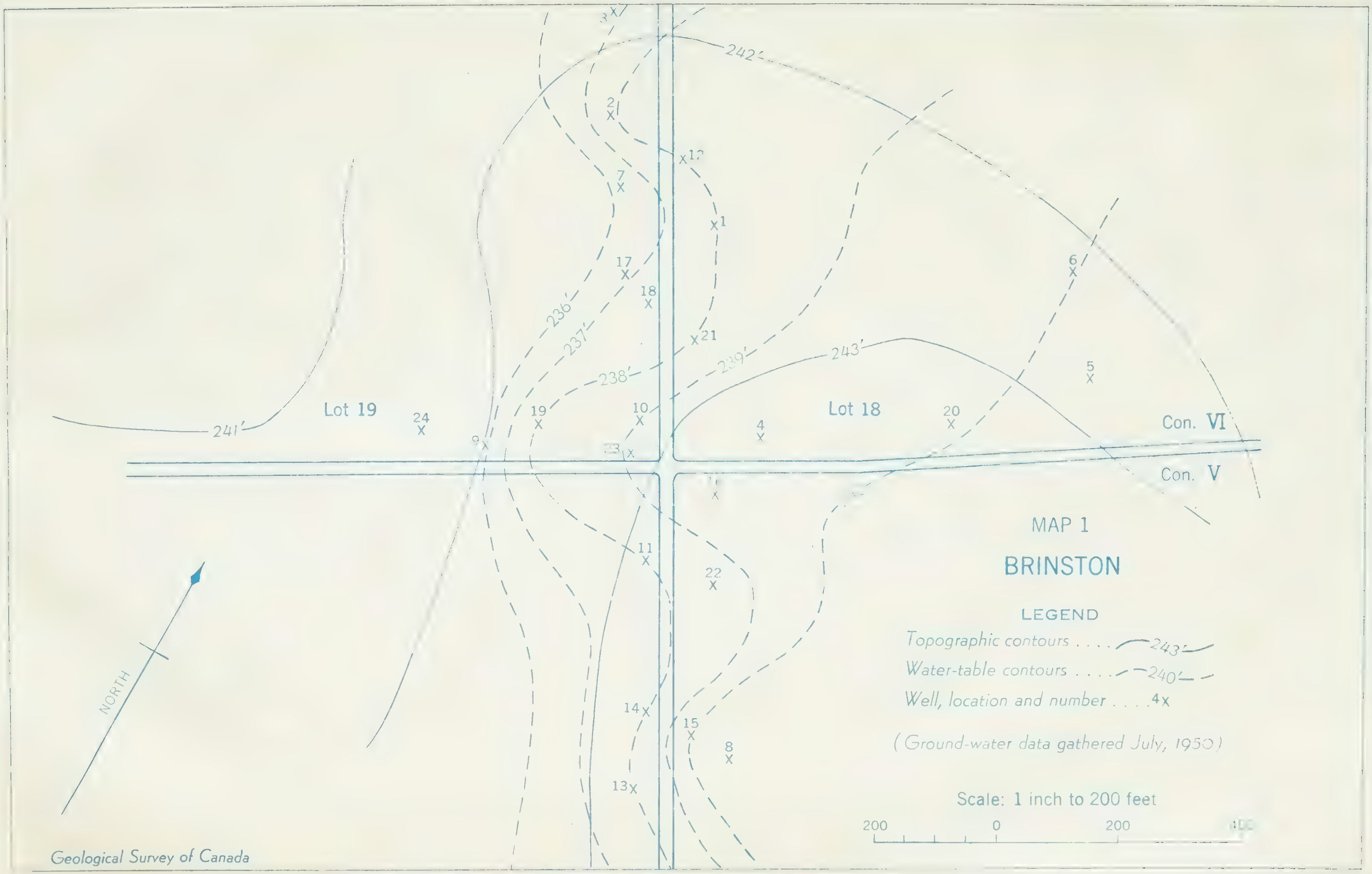
Summary of Wells and Springs used as a source of Water Supply (Communities)

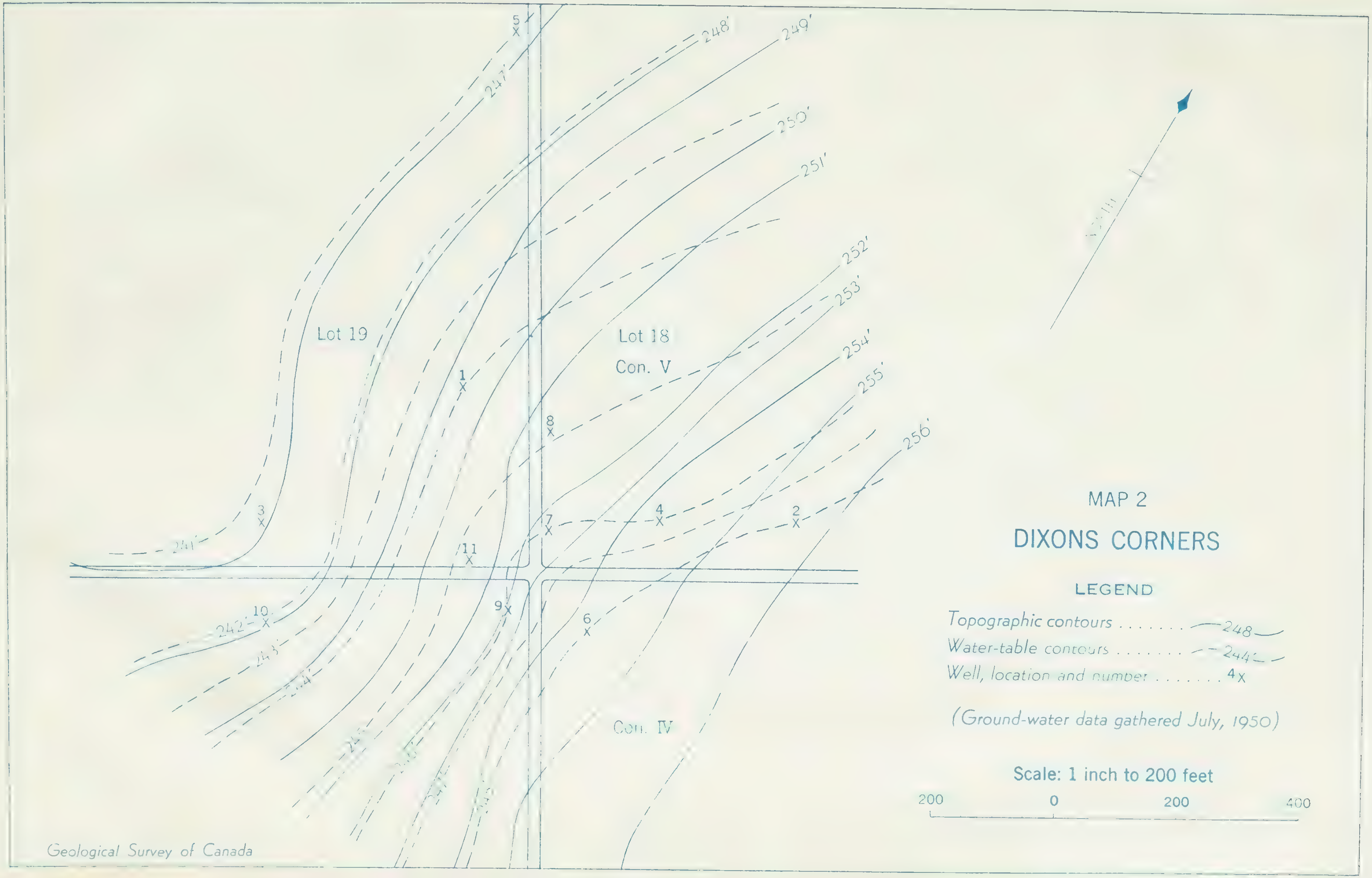
Wells and Springs	Brinston	Dixons Corners	Dundela	Total number in communities	Per cent of total
Total number	24	11	14	49	
Dug	22	9	12	43	87.9
Bored	0	0	0	0	0.0
Drilled	2	2	2	6	12.2
Feet deep					
Wells 0-20	18	5	3	26	53.1
20-40	4	4	9	17	34.7
40-60	0	2	0	2	4.1
60-80	1	0	0	1	2.0
80-100	0	0	1	1	2.0
Over 100	1	0	0	1	2.0
Depth unknown	0	0	1	1	2.0
Wells that yield hard water	23	11	14	48	98.0
Soft water	1	0	0	1	2.0
Salty water	0	0	0	0	0.0
Wells with aquifer in clay	20	9	0	29	59.2
In sand	2	0	0	2	4.1
In gravel	0	1	0	1	2.0
In clay till	0	0	12	12	24.5
In bedrock	2	1	2	5	10.2
Unknown	0	0	0	0	0.0
Well types: flowing artesian	0	0	0	0	0.0
Non-flowing artesian	3	2	0	5	10.1
Non-artesian	18	9	13	40	81.8
Intermittent	3	0	1	4	8.1
Dry holes	0	0	0	0	0.0
Not used	5	1	1	7	14.1
Springs	0	0	0	0	0.0

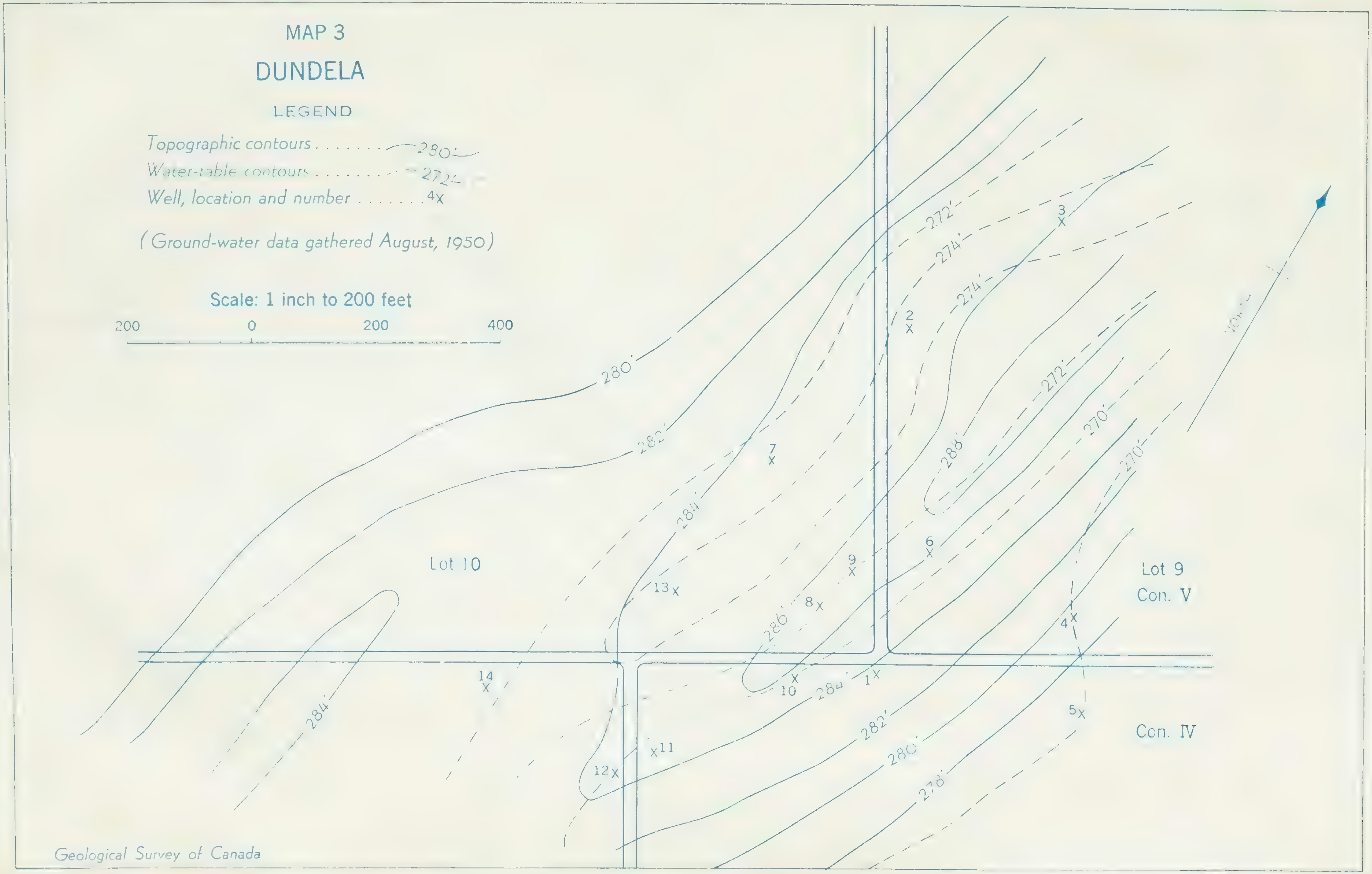
ANALYSES OF WELL WATERS FROM MATILDA TOWNSHIP, DUNDAS COUNTY, ONTARIO

						Constituents as analysed (parts per million)										Hardness as CaCo (pts/million)		
Sample number	Owner	Lot	Concession	Depth of Well Feet	*Aquifer	Residue on evaporation (pts/million)	Calcium (Ca)	Magnesium (Mg)	Sodium (Ne)	Potassium (K)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Bicarbonate (HCO_3)	Carbonato (CO_3)	Silica Col, (S_1O_2)	Ca hardness	Ma hardness	Total hardness
1	W. McGowan	9	V	23	C.T.	700	112.0	28.6	20.5	15.0	41.6	97.0	64.2	255.7	0	7.8	279.4	117.7	397.1
2	W. McGowan	9	V	96	O.	1,339	160.5	50.0	23.4	224.0	197.1	67.3	248.1	517.5	0	12.2	400.5	205.8	606.3
3	P. Murphy	18	V	16	C.	610	92.5	32.8	21.3	50.0	81.5	30.7	69.8	341.6	0	11.6	230.8	135.0	365.8
4	Coleman Bros. garage	18	V	23	C.	324	75.1	22.1	12.0	2.9	17.7	5.4	1.8	343.8	0	12.4	187.4	90.9	278.3
5	A. R. Collison	22	VI	39	C.	506	40.0	21.6	126.0	9.2	24.3	121.5	0	293.0	0	10.6	99.8	90.1	189.9
6	R. Ennis	23	VI	100	St.M.	704	28.0	23.4	204.0	16.4	14.8	259.9	7.1	262.5	0	10.8	69.9	96.3	166.2
7	Glen Stewart cheese factory	31	VI	65	R.	400	28.9	20.5	88.0	8.5	21.8	70.0	1.0	251.1	9.6	10.2	72.1	84.4	156.5
8	C. Thorpe	23	VII	93	St.M.	888	48.5	31.2	216.0	9.6	44.9	343.0	1.4	235.7	0	10.2	121.0	128.4	249.4
9	E. Kirker	26	VII	47	R.	576	87.1	31.2	77.0	8.2	73.3	60.0	1.4	433.1	0	10.6	217.3	128.4	345.7
10	P. Arbic	10	VIII	20	C.	808	93.4	53.1	61.2	2.4	102.1	109.9	57.6	275.7	16.8	14.4	233.0	218.0	451.5
11	Ellis Bros.	19	VIII	85	St.M.	1,066	83.5	100.3	30.4	52.0	153.1	117.8	11.1	497.8	0	23.2	208.3	412.7	621.0
12	M. R. Sullivan	21	VIII	47	R.	1,146	81.7	67.3	42.0	32.4	130.5	72.8	159.5	257.2	8.2	10.0	203.8	276.9	480.7

*C. - clay　　G. - gravel　　O. - Ottawa formation
S. - sand　　C.T. - clay till　　R. - Rockcliffe formation
St.M. - St. Martin formation


MAP 1
BRINSTON
LEGEND
Topographic contours . . . . 243'
Water-table contours . . . . 240'
Well, location and number 4x
(Ground-water data gathered July, 1950)
Scale: 1 inch to 200 feet
200
0
200
Lot 19
Lot 18
Con. VI
Con. V
242'
243'
241'
236'
237'
238'
239'
NORTH
Geological Survey of Canada


MAP 2
DIXONS CORNERS
LEGEND
Topographic contours 248
Water-table contours 244
Well, location and number 4x
(Ground-water data gathered July, 1950)
Scale: 1 inch to 200 feet
200
0
200
400
Lot 19
Lot 18
Con. V
Con. IV
248'
249'
250'
251'
252'
253'
254'
255'
256'
247'
241'
242'
243'
1
2
3
4
5
6
7
8
9
10
11
Geological Survey of Canada


MAP 3
DUNDELA
LEGEND
Topographic contours . . . . 280'
Water-table contours . . . . 272'
Well, location and number 4x
(Ground-water data gathered August, 1950)
Scale: 1 inch to 200 feet
200
0
200
400
280'
282'
284'
286'
288'
272'
274'
270'
278'
Lot 10
Lot 9
Con. V
Con. IV
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Geological Survey of Canada

Community of Brinston

WELL RECORDS Matilda Township Dundas County, Province Ontario

LOCATION				DESCRIPTION					WATER LEVEL July 1950		PRINCIPAL WATER-BEARING BED			WATER		REMARKS
Well No.	Conc.	Lot	Owner	Type	Topographic Situation	Elevation*	Depth	Classification +	Above + Below − Surface	Elevation	Depth	Elevation	Aquifer	Quality	Used for °	
1	6	18	J. Adams	Dug	Plain	243	12	N.A.	-5M	238			Clay	Hard, clear	D.	Sufficient
2	6	19	Boyd	"	"	244	14	"	-6M	238			Sand (?)	" "	D.	Sufficient; at house
3	6	19	Boyd	Drilled(?)	"	242	39	N.F.A.	-12M	230			Sand	" "	S.	Sufficient; at barn
4	6	19	H. Boyd	Dug	"	243	15	I.W.	-5M	238			Clay	" "	S.	Goes dry during summer
5	6	18	H. Boyd	"	"	246	20	N.A.	-8M	238			"	" "	D.	Sufficient
6	6	18	H. Boyd	"	"	245	22	"	-5M	248			"	" "	S.	Sufficient for 15 head of stock
7	6	19	A. Brinston	"	"	242	14	"	-6M	236			"	" "	D.	Sufficient
8	5	18	Coleman Bros.	"	"	241	23	"	-4M	237			"	" "	D.	Sufficient for garage; 55°F
9	6	19	A. Coones	"	"	242	15	"	-6M	236			"	" "	D.	Sufficient
10	6	19	M. J. Davidson	"	"	245	14	"	-6M	239			"	" "		Not used
11	5	19	C. Grillson	"	"	243	14	"	-5M	238			"	" "	D.	Sufficient
12	6	18	E. Hamilton	"	"	242	12	"	-4M	238			"	" "	D.	"
13	5	19	R. Innes	"	"	241	11	"	-3M	238			"	" "		Not used
14	5	19	J. McGowan	"	"	243	13	"	-5M	238			"	" "	D.	Sufficient
15	5	18	E. McShane	"	"	242	11	"	-2M	240			"	" "		Not used
16	5	18	C. N. Murphy	"	"	243	15	"	-7M	236			"	" "	D.	Sufficient
17	6	19	A. S. Peterson	"	"	243	14	"	-6M	237			"	" "	D.	Not used
18	6	19	A. S. Peterson	"	"	243	12	"	-3M	240			"	" "		Not used
19	6	19	Wallace	"	"	243	183	N.F.A.	-5M	238			St. Martin	" "	D.	Sufficient; depth to bedrock unknown
20	6	18	Cheese Factory	"	"	243	65	"	-7M	236			"	soft, "	D.	Sufficient; yields 400 gallons per day; bedrock at 20 feet
21	6	18	Farmers' Co-operative	Dug	"	243	65	N.A.	-5M	238			Clay	hard, "		Not used
22	5	18		"	"	246	14	I.W.	-5M	238			"	" "	D.	Goes dry during summer
23	6	19		"	"	243	13	N.A.	-4M	239			"	" "	D.	Sufficient
24	6	19		"	"	242	8	I.W.	-4M	238			"	" "	D.	Goes dry during summer

*All elevations in feet above sea level.
†Sample taken for analysis.
M – Measured

+ Classification: F.A.—Flowing Artesian. N.A.—Non-Artesian. N.F.A.—Non-Flowing Artesian.

° Used for: S—Stock. I—Irrigation. M—Municipal. D—Domestic. G—Greenhouse or Garden.

Community of Dixons Corners

WELL RECORDS

Matilda Township Dundas County, Province Ontario

LOCATION				DESCRIPTION					WATER LEVEL July 1950		PRINCIPAL WATER-BEARING BED			WATER		REMARKS
Well No.	Conc.	Lot	Owner	Type	Topographic Situation	Elevation*	Depth	Classification +	Above + Below − Surface	Elevation	Depth	Elevation	Aquifer	Quality	Used for °	
1	5	19	H.L. Boyd	Dug	Plain	248	20	N.A.	-4M	244			Clay	Hard, clear	D.	Sufficient
2	5	18	C. Hanson	"	"	256	22	"	-8M	248			"	" "	D.	"
3	5	19	H. Locke	Drilled	"	247	39	N.F.A.	-2M	245			Gravel under clay	" "	D.S.	Sufficient; sometimes flows during spring
4	5	18	Dairy	Dug	"	254	17	N.A.	-8M	246			Clay	" "	D.	Sufficient; yields 450 gallons per day
5	5	19	School	"	"	247	22	"	-6M	241			"	" "	D.	Sufficient
6	4	19		"	"	254	19	"	-6M	248			"	" " †	D.	"
7	5	18	P. Murphy	"	"	252	16	"	-6M	246			"	" "	D.	Sufficient; used by several families; 50°F.
8	5	18		"	"	252	12	"	-4M	247			"	" cloudy		Not used
9	4	19		"	"	252	21	"	-6M	246			"	" Clear	D.	Sufficient
10	4	19		"	"	248	12	"	-6M	242			"	" sulphur	D.	"
11	5	19		Drilled	"	251	45	N.F.A.	-5 M	246			St. Martin	" Clear	D.	" depth to bedrock unknown

*All elevations in feet above sea level.
†Sample taken for analysis.
M - Measured

+ Classification: F.A. -Flowing Artesian. N.A. -Non-Artesian. N.F.A. -Non-Flowing Artesian.

° Used for: S—Stock. I—Irrigation. M—Municipal. D—Domestic. G—Greenhouse or Garden.

Community of Dundela

WELL RECORDS Matilda Township Dundas County, Province Ontario

LOCATION				DESCRIPTION					WATER LEVEL July 1950		PRINCIPAL WATER-BEARING BED			WATER		REMARKS
Well No.	Conc.	Lot	Owner	Type	Topographic Situation	Elevation°	Depth	Classification +	Above + Below − Surface	Elevation	Depth	Elevation	Aquifer	Quality	Used for °	
1	4	9	W. A. Gordier	Dug	Hill	286	24	N.A.	-12M	274			Clay till	Hard, clear†	D.	Sufficient supply; at house
2	5	9	W. McGowan	"	Slope	287	23	"	-12M	275			" "	" "†	D.	" " " " 48°F.
3	5	9	W. McGowan	Drilled	"	286	96	"	-22M	264			Ottawa	" "	S.	Sufficient for 20 head of stock; at barn 48°F
4	5	9	S. C. Lapere	Dug	Hill	280	17	"	-10M	270			Clay till	" "	D.	Never goes dry; at house
5	4	9	E. Lapere	"	"	277	12	"	-7M	270			" "	" "	D.	Sufficient supply; at house
6	5	9	A. McIntosh	"	"	286	23	"	-15M	271			" "	" "	D.	" " " "
7	5	10	A. McIntosh	"	Slope	285	20	"	-18M	267			" "	" "	S.	Sufficient for 13 head of stock; at barn
8	5	10	H. McIntosh	"	Hill	287	27	"	-15M	272			" "	" "	D.	Sufficient supply; at house
9	5	10	Fred Morrell	"	"	287	24	I.W.	-15M	272			" "	" "	D.	Insufficient supply; at house
10	4	9	S. Pitt	"	"	285	31	N.A.	-15M	270			" "	Hard, Clear	D.	Sufficient supply; at house
11	4	9	J. Tuttle	"	"	287	31	"	-18M	269			" "	" "	D.	" " " "
12	4	10	J. Tuttle	"	"	287	36	"	-17M	270			" "	Hard, sulfur	S.	Sufficient for 30 head of stock; at barn
13	5	10	United Church Par.	"	Slope	286	29	"	-11M	275			" "	Hard, clear	D.	Sufficient supply; at house
14	4	10	Dundela School	Drilled	Plain	283							Bedrock (?)	Hard cloudy		Not used

° Elevations in feet above sea level + Classification F.A.—Flowing Artesian. N.A.—Non-Artesian ° Used for S—Stock. I—Irrigation. M—Municipal
† Taken for analysis N.F.A.—Non-Flowing Artesian. D—Domestic. G—Greenhouse or Garden
M - Measured

CANADA

DEPARTMENT OF MINES

AND

TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

WATER SUPPLY PAPER No. 311

GROUND-WATER RESOURCES OF TOWNSHIPS 31 to 34, RANGES 21 to 24, WEST OF 4th MERIDIAN ALBERTA

(Three Hills Area)

By

A. Mac S. Stalker

OTTAWA

1953

NOTE:

Because of difficulties involved in reproduction, the tables of well records referred to are not included with this report. Information regarding individual wells may be obtained by writing to the Director, Geological Survey of Canada, Ottawa.

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CONTENTS

<u>Illustrations</u>

INTRODUCTION

The survey of the ground-water resources of the Red Deer region, Alberta, was resumed during the field season of 1946, and much information on these resources was obtained by a compilation of records of water wells.

A division has been made in the well records, in so far as possible, between the glacial and bedrock water-bearing sands. The water records themselves were obtained mostly from the well owners, some of whom had acquired the land after the water supply had been found, and hence had no personal knowledge of the water-bearing beds that had been encountered in their wells. Also, the elevations of the wells were taken by aneroid barometer and are, consequently, only approximate. In spite of these defects, however, it is hoped that the publication of these water records may prove of value to the farmers, town authorities, and drillers in their efforts to obtain adequate water supplies.

Publication of Results

The essential information pertaining to ground-water conditions is being issued in reports that in Saskatchewan cover each municipality, and in Alberta cover each square block of sixteen townships beginning at the 4th meridian and lying between the correction lines. The secretary-treasurer of each municipality in Saskatchewan and Alberta will be supplied with the information covering that municipality. Copies of the reports will also be available for study at offices of the Provincial and Federal Departments. Further assistance in the interpretation of the reports may be obtained by applying to the Chief Geologist, Geological Survey, Ottawa. Technical terms used in the report are defined in the glossary.

How to Use the Report

Anyone desiring information concerning ground water in any particular locality will find the available data listed in the well records. These should be consulted to see if a supply of water is likely to be found in shallow wells sunk in the glacial drift, or whether a better supply may be obtained at greater depth in the underlying bedrock formations. The wells in glacial drift commonly show no regional level, as the sands or gravels in which the water occurs are irregularly distributed and of limited extent. As the surface of the ground is uneven, the best means of comparing water wells is by the elevations of their water-bearing beds. For any particular well this elevation is obtained by subtracting the figure for the depth of the well to the water-bearing bed from that for the surface elevation at the well. For convenience, both the elevation of the wells and the elevation of the water-bearing bed or beds in each well are given in the well-record tables. Where water is obtained from bedrock, the name of the formation in which the water-bearing sand occurs is also listed in these tables, and this information should be used in conjunction with that on bedrock formations, provided in the report, which describes these formations and gives their thickness and sequence. Where the level of the water-bearing sand is known, its depth at any point can easily be calculated by subtracting its elevation, as given in the well-records tables, from the elevation of the surface at that point.

With each report is a map consisting of two figures. Figure 1 shows the distribution and type of surface deposits and bedrock formation that occur in the area. Figure 2 shows the locations of all wells for which records are available, the class of well at each location, and the contour lines or lines of equal elevation. The elevation at any location can thus be roughly judged from the nearest contour line, and the records of the wells show at what levels water is apt to be encountered. The depth of the well can then be calculated, and some information on the character and quantity of water can be obtained from a study of the records of surrounding wells.

GLOSSARY OF TERMS USED

Alkaline. The term "alkaline" has been applied rather loosely to some ground waters that have a peculiar and disagreeable taste. In the Prairie Provinces, water that is commonly described as alkaline usually contains a large amount of sodium sulphate and magnesium sulphate, the principal constituents of Glauber's salt and Epsom salts respectively. Most of the so-called alkaline waters are more correctly termed sulphate waters, many of which may be used for stock without ill effect. Water that tastes strongly of common salt is described as salty.

Alluvium. Deposits of earth, clay, silt, sand, gravel, and other material on the flood-plains of modern streams and in lake beds.

Aquifer. A porous bed, lens, or pocket in unconsolidated deposits or in bedrock that carries water.

Buried pre-Glacial Stream Channel. A channel carved into bedrock by a stream before the advance of the continental ice-sheet, and subsequently either partly or wholly filled in by sands, gravels, and boulder clay deposited by the ice-sheet or later agencies.

Bedrock. Bedrock, as here used, refers to partly or wholly consolidated deposits of gravel, sand, silt, clay, and marl that are older than the glacial drift.

Coal Seam. The same as a coal bed. A deposit of carbonaceous material formed from the remains of plants by partial decomposition and burial.

Contour. A line on a map joining points that have the same elevation above sea-level.

Continental Ice-sheet. The great ice-sheet that covered most of the surface of Canada many thousands of years ago.

Escarpment. A cliff or a relatively steep slope separating level or gently sloping areas.

Flood-plain. A flat part in a river valley ordinarily above water but covered by water when the river is in flood.

Glacial Drift. The loose, unconsolidated surface deposits of sand, gravel, and clay, or a mixture of these, that

were deposited by the continental ice-sheet. Clay containing boulders forms part of the drift and is referred to as glacial till or boulder clay. The glacial drift occurs in several forms:

(1) Ground Moraine. A boulder clay or till plain (includes areas where the glacial drift is very thin and the surface uneven).

(2) Terminal Moraine or Moraine. A hilly tract of country formed by glacial drift that was laid down at the margin of the continental ice-sheet during pauses in its retreat. The surface is characterized by irregular hills and undrained basins.

(3) Glacial Outwash. Sand and gravel plains or deltas formed by streams that issued from the continental ice-sheet.

(4) Glacial Lake Deposits. Sand and clay plains formed in glacial lakes during the retreat of the ice-sheet.

Ground Water. Sub-surface water, or water that occurs below the surface of the land.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it is first encountered.

Impervious or Impermeable. Beds, such as fine clays or shale, are considered to be impervious or impermeable when they do not permit of the perceptible passage or movement of ground water.

Pervious or Permeable. Beds are pervious when they permit of the perceptible passage or movement of ground water, as for example porous sands, gravel, and sandstone.

Pre-Glacial Land Surface. The surface of the land before it was covered by the continental ice-sheet.

Recent Deposits. Deposits that have been laid down by the agencies of water and wind since the disappearance of the continental ice-sheet.

Unconsolidated Deposits. The mantle or covering of alluvium and glacial drift consisting of loose sand, gravel, clay and boulders that overlies the bedrock.

Water-table. The upper limit of the part of the ground wholly saturated with water. This may be very near the surface or many feet below it.

Wells. Holes sunk into the earth so as to reach a supply of water. When no water is obtained they are referred to as dry holes. Wells in which water is encountered are of three classes.

(1) Wells in which the water is under sufficient pressure to flow above the surface of the ground.

(2) Wells in which the water is under pressure but does not rise to the surface.

(3) Wells in which the water does not rise above the water-table.

BEDROCK FORMATIONS OF EAST-CENTRAL ALBERTA

The formations that outcrop in east-central Alberta are of Tertiary and Upper Cretaceous age, and consist entirely of relatively soft shales and sandstones, with some bands of hard sandstone and layers of ironstone nodules. The succession, character, and estimated thickness of the formations are shown in the following table:

Age	Formation	Character	Thickness Feet
Tertiary	Paskapoo	Light grey sandstone, in part carbonaceous; shale; small amounts of siliceous limestone and volcanic dust; coal seams.	800 ±
Upper Cretaceous	Edmonton	Grey to white, bentonitic sands and sandstones, with grey and greenish shales; coal seams prominent in some areas, as at Drumheller.	1,000 to 1,150
	Bearpaw	Dark shales, green sands with smooth, black chert pebbles; partly non-marine, with white bentonic sands, carbonaceous shales, or thin coal seams similar to those in Pale Beds; shales at certain horizons contain lobster-claw nodules and marine fossils; at other horizons selenite crystals are abundant.	300 to 600
	Pale and Variegated Beds	Light grey sands with bentonite; soft, dark grey and light grey shales with selenite and ironstone; carbonaceous shales and coal seams; abundant selenite crystals in certain layers.	600 ±
	Birch Lake (?)	Grey sand and sandstone in upper part; middle part of shales and sandy shales, thinly laminated; lower part with grey and yellow weathering sands; oyster bed commonly at base.	100 ±
	Grizzly Bear	Mostly dark grey shale of marine origin, with a few minor sand horizons; selenite crystals and nodules up to 6 or 8 inches in diameter.	100 -
	Ribstone Creek	Grey sands and sandstones at the top and bottom with intermediate sands and shales; mostly non-marine, but middle shale in some areas is marine.	325 -

WATER ANALYSES

Introduction

The following discussion of water analyses is included to assist those who wish to know the effect of various mineral constituents in well water, which give the water in some wells certain peculiar qualities.

Discussion of Chemical Determinations

The dissolved mineral constituents vary with the material encountered by the water in its migration to the reservoir bed. The mineral salts present are referred to as the total dissolved solids, and they represent the residue when the water is completely evaporated. This is expressed quantitatively as "parts per million", which refers to the proportion by weight in 1,000,000 parts of water. A salt when dissolved in water separates into two chemical units called "radicals", and these are expressed as such in the chemical analyses. In the one group is included the metallic elements of calcium (Ca), magnesium (Mg), and sodium (Na), and in the other group are the sulphate (SO_4), chloride (Cl), and carbonate (CO_3) radicals.

Mineral Constituents Present

Calcium (Ca) in the water comes from mineral particles present in the surface deposits, the chief source being limestone, gypsum, and dolomite. Fossil shells provide a source of calcium, as does also the decomposition of igneous rocks. The common compounds of calcium are calcium carbonate ($CaCO_3$) and calcium sulphate ($CaSO_4$).

Magnesium (Mg) is a common constituent of many igneous rocks and, therefore, very prevalent in ground water. Dolomite, a carbonate of calcium and magnesium, is also a source of the mineral. The sulphate of magnesium ($MgSO_4$) combines with water to form "Epsom salts", and if present in large amounts imparts a bad taste and is detrimental to the health.

Sodium (Na) is derived from a number of important rock-forming minerals, so that sodium sulphate and carbonate are very common in ground waters. Sodium sulphate (Na_2SO_4) combines with water to form "Glauber's salts", which if present in amounts over 1,200 parts per million makes the water unfit for domestic use or for irrigation. Sodium carbonate (Na_2CO_3) or "black alkali" waters are mostly soft, the degree of softness depending upon the ratio of sodium carbonate to the calcium and magnesium salts. Waters containing sodium carbonate in excess of 200 parts per million are unsuitable for irrigation.

Chlorine (Cl) is, with a few exceptions, expressed as sodium chloride (NaCl), which is common table salt. When found in water in excess of 400 parts per million it renders the water unfit for domestic use.

Iron, when present in more than 0.1 parts per million, will settle out of the water as a red precipitate on exposure to the air. Water that contains not more than 0.5 parts per million

is considered the usual upper limit for potable water, but this amount is often exceeded. A water that contains considerable iron will stain porcelain, enamel ware, and clothing that is washed in it, but the iron can be almost completely removed by aeration and filtration of the water.

Hardness. Hardness is of two kinds, temporary and permanent. Temporary hardness is caused by calcium and magnesium bicarbonates, which are soluble in water but are precipitated as insoluble normal carbonates by boiling, as shown by the scale that forms in teakettles. Permanent hardness is caused by the presence of calcium and magnesium sulphates, and is not removed by boiling. Waters grade from very soft to very hard, and can be classified according to the following system[1].

[1] The "Examination of Waters and Water Supplies"; Thresh and Beale, Fourth Ed. 1933, p. 21.

A water under 50 degrees (that is, parts per million) of hardness may be said to be very soft.

A water with 50 to 100 degrees of hardness may be said to be moderately soft.

A water with 100 to 150 degrees of hardness may be said to be moderately hard.

A water with more than 200 and less than 300 degrees of hardness may be said to be hard.

A water with more than 300 degrees of hardness may be said to be very hard.

Hard waters are usually high in calcium carbonate. Almost all of the waters from the glacial drift are of this type, particularly those not associated with sand and gravel deposits that come close to the surface.

In soft water the calcium carbonate has been replaced by sodium carbonate, due to natural reagents present in the sands and clays. Bentonite and glauconite are two such reagents known to be present. Montmorillonite, one of the clay-forming minerals, has the same property of softening water, owing to the absorbed sodium that is available for chemical reaction.[2]

[2] Piper, A.M.: "Ground Water in Southern Pennsylvannia", Penn. Geol. Surv., 4th series.

If surface water reaches the lower sands by percolating through the higher beds it may be highly charged with calcium salts before reaching the bedrock formations containing bentonite or glauconite. The completeness of the exchange of calcium carbonate for sodium carbonate will, therefore, depend upon the length of time that the water is in contact with the softening reagent, and also upon the amount of this material present. The rate of movement of underground water will, consecuently, be a factor in determining the extent of the reaction.

TOWNSHIPS 31 TO 34, RANGES 21 TO 24, WEST OF FOURTH MERIDIAN, ALBERTA

Introduction

The investigation of ground-water resources in Alberta was continued during the summer of 1949 by the writer, ably assisted by P. J. S. Byrne. The surface deposits were also mapped, and the relation of both the surface deposits and the underlying bedrock to the ground-water supply studied. The following report is based on information gained at that time.

Physical Features

Red Deer River flows southward through the eastern townships of the area in a valley 450 to 700 feet deep and 1 mile to 2 miles wide, which has the steep walls and canyon-like form of a new drainage channel developed in unresistant material in a semi-arid region. Many deep gullies, as much as 4 miles long, are tributary to it. The land a mile or so back is singularly unaffected by the nearness of the river, with no general slope towards it, and with much the same general topographic features as occur in places remote from the river. Big Valley Creek enters Red Deer River in the northeast corner of the area through a gully-like valley and is the only large tributary. In the area mapped the river drops from about 2,325 to about 2,225 feet above sea-level, and thus has a gradient of 3 or 4 feet to a mile.

Three other large valleys strike southeast through the area, with courses parallel with that of Red Deer River in townships 31, 32, and 33. Threehills Creek crosses the southwest corner of the area with a flat-floored valley as much as 4 or 5 miles wide and generally about 300 feet deep. Ten miles east of this Ghostpine Creek flows in a parallel direction along another flat-floored valley 5 miles wide and 250 feet deep. The third parallel valley, which joins the Red Deer at its bend in township 33, does not now contain any stream, but is about 200 feet deep and 3 or 4 miles wide. Small streams are

numerous, and the area, and especially the southern half, is well drained, though in the north a few ponds and sloughs collect water.

Several hills, such as Three Hills in the west, and others in the northwest, reach more than 3,100 feet above sea-level, and others, present in all regions, rise above 3,000 feet. Most of the area is more than 2,700 feet above sea-level, and the lowest point, where Red Deer River leaves the area, is about 2,200 feet. The topography consists of broad, bedrock hills, ridges, and divides, commonly gullied, separated by wide, mostly gently-walled, valleys. Local relief is, in places, 200 to 300 feet. Except in the north and east, drift hills are uncommon, and the surface has a generally smooth appearance.

Geology

Glacial deposits cover almost the entire area. The underlying bedrock is either Edmonton formation or the overlying Paskapoo formation, the latter occupying some three-quarters of the area. Older formations, mentioned in a table earlier in the report, underlie the Edmonton, but at too great a depth, probably not less than 1,000 feet, to affect surface features or water supply.

The prevailing dip of the bedrock is to the west and southwest, and in those directions 300 or 400 feet of Paskapoo formation may cover the Edmonton. This cover thins to the east, where the Edmonton commonly underlies the unconsolidated material. Practically all the exposed bedrock is Edmonton formation, as Red Deer River, Big Valley Creek, and most of the gullies cut into this formation. Bedrock is exposed or very near the surface in about 45 square miles, mostly in Red Deer Valley, but also in several small areas in the southwest.

Edmonton Formation. The name Edmonton formation was first applied to the beds containing coal in the Edmonton area, and later to the same beds in adjoining areas. The formation has a total thickness

of 1,000 to 1,150 feet, but is bevelled off eastwards, and the eastern edge of the formation follows a northwest line from Coronation through Tofield to a point on North Saskatchewan River about midway between Edmonton and Fort Saskatchewan. No Edmonton beds occur northeast of this line, but as the formation dips to the southwest it becomes progressively thicker in that direction.

The Edmonton formation consists of poorly bedded, grey and greenish grey clay shale, coal seams, and sand and sandstone that contain clay and a white material known as bentonite. Bentonite when wet is very sticky and swells greatly in volume and when dry tends to whiten the beds containing it. Such beds are relatively impervious to water, and at the surface produce the "burns" of barren ground where vegetation is scanty or absent.

Paskapoo Formation. This formation was first named by Tyrrell from exposures of the lower part of the formation along Blindman River near its confluence with the Red Deer. It is composed essentially of sandstone and shale deposited in fresh water and includes some thin coal seams and carbonaceous beds. The basal beds, which are of importance in this area, are massive, crossbedded sandstone that weathers buff-yellow, and are in striking contrast with the underlying, light-coloured, bentonitic clay of the Edmonton formation. About 150 to 200 feet above the base of the formation are a series of lenses of siliceous limestone containing fossil gastropods and pelecypods. This limestone may be largely the cause of the extreme hardness of some of the ground water in the area.

Unconsolidated Deposits. During Pleistocene or Glacial time, great accumulations of ice formed at various centres in northern Canada. This ice moved out in all directions from these centres and covered large regions with what has been called the continental ice-sheet. As the ice advanced, it picked up great quantities of loose rock debris that was deposited when the ice finally melted. This material is

unconsolidated, and is commonly called glacial drift.

The present area was entirely covered by one or more continental ice-sheets during Pleistocene time, and the final retreat of the ice left the bedrock buried to various depths of glacial drift, the unconsolidated deposits of the area. Most of the glacial drift consists of boulders and pebbles of various compositions and sizes embedded in a matrix of clay or sandy clay to form a more or less impervious mass known as boulder clay or till. Irregularly intermingled with this till, and also lying above it, are beds, pockets, and lenses of sand and gravel that form the water-bearing members or aquifers.

The character of the till changes from east to west. In the east most of it is very sticky, grey in colour, and contains much clay but little sand. In the west, however, where there is a greater content of material from the Paskapoo formation, the till, although containing much clay, is brown, more sandy, and slightly less sticky. Stones are nowhere common, and pockets and lenses of gravel are almost entirely absent.

The unconsolidated deposits are rarely more than 30 feet thick and probably average less than 20 feet in thickness. They are thickest in the north and northeast.

Ground Moraine. This type of glacial drift is chiefly till or boulder clay laid down beneath the ice-sheet. It commonly has a flat or gently rolling surface, and covers 368 square miles, or about two-thirds of the area.

End Moraine. Part of the material carried by the ice-sheet is dropped at its front or margin during pauses in the general retreat of the melting glacier. It consists of till, silt, sand, and gravel gathered during the advance of the ice-sheet. Much of the clay, silt, and fine sand may have been carried away by melt-water from the glacier,

and the material forming end moraine is mostly coarser than that seen in ground moraine. It is characteristically arranged in hummocks and undrained or poorly drained hollows. About 65 square miles of the area, mostly in the north and northeast, is covered with low, weakly developed, end moraine.

Glacial-lake Deposits. During the melting back of the ice-sheet many lakes were formed where the normal drainage was temporarily blocked by lobes of ice or masses of glacial debris. Sand, silt, and clay were washed into these lakes and there deposited. Draining or lowering of these lakes exposed this material. Such deposits, in this area mostly clay, cover about 95 square miles in the valleys of Threehills and Ghostpine Creeks.

Some small areas of stream and glacial-outwash gravels are present, and will be mentioned in the descriptions of the various townships.

Water Supply

With a few exceptions to be mentioned later, sufficient supplies of water can be obtained anywhere in the area. The quality is generally good, and chemical analysis of representative samples are given later. The average depth of drilled well is about 135 feet, with the deepest wells in the east near Red Deer Valley, where many are more than 250 feet deep. The rise of water in the wells is small or negligible in the east, but is greater in the west.

The average yearly precipitation in the area ranges from about 14 to 18 inches, and the region is semi-arid. One-third to one-quarter of the precipitation is in the form of snow. As the area is generally well drained, trees few, vegetation light, and much of the surface material nearly impermeable, run-off is quick and proportionately large. Also, as humidity is generally low and the summers warm, the rate of

evaporation is high. The proportion of the precipitation and the total amount of water that seeps into the unconsolidated deposits and bedrock to become ground water is, therefore, relatively small. However, as the area is rather thinly populated, the amount of ground water is sufficient for present use. Red Deer River is the only large source of surface water, as other streams are nearly dry much of the summer.

Of the surface deposits only the end moraine and lake sand are important in water supply, and even they are seldom of much value and generally yield only a fair supply or one insufficient for local purposes. Any attempt to obtain water from ground moraine or lake clay is inadvisable. Water found in the Pleistocene deposits is mostly hard, as it contains much calcium, and may also contain noticeable amounts of iron.

Of the 337 wells recorded, 318 draw from bedrock aquifers, and about 175 of these, mostly in the east, depend upon aquifers in the Edmonton, whereas about 143, largely in the west, tap aquifers in the Paskapoo. Determination of the formation in which an aquifer lies is commonly difficult as the contact between the two formations is very uneven.

The Edmonton contains many isolated lenses of sand irregularly distributed through the formation. Some zones contain more of these lenses than others and, as the water is in the sand, these zones are the more likely to yield water. Water is also frequently found either above or below coal seams. As the beds dip to the west and the surface of the ground rises to the west, an aquifer becomes more deeply buried in that direction, and others appear above it. Thus few aquifers are traceable very far in an east-west direction but may be traced farther north and south.

Although aquifers in the Paskapoo are more commonly used in the western part of the area, the Edmonton beneath it is everywhere a potential source of water. The upper part of the Edmonton, which is present in this part of the area, contains much water, but only yields it slowly because of its generally small grain size and high bentonitic content. Large supplies are thus seldom obtained from it.

Water entering the Edmonton beds through glacial deposits is commonly charged with calcium carbonate and, consequently, hard. Sodium carbonate from the Edmonton formation, however, replaces the calcium carbonate, softening the water. Generally the longer water is in contact with the Edmonton formation the softer it becomes, and although hard or medium hard water may occur near the surface, deeper down all the water is soft. Sodium carbonate is the principal mineral matter found in water from the Edmonton formation, but small amounts of iron occur in places, and some carbonaceous material from water near coal seams.

The Paskapoo formation generally contains abundant water, mostly in porous sand lenses that are more common in some horizons of the formation than in others. None of these lenses can be traced far, but in most places they overlap to form aquifer zones. The water of each of these zones bears distinguishing characteristics. As with the Edmonton formation, these aquifer zones become deeper to the west, and finally can be traced no farther.

The sand of the Paskapoo formation is commonly coarse, and thus will yield large quantities of water rapidly. This, however, is a drawback where the Paskapoo forms high ground or is cut by valleys, for it also allows easy drainage to lower ground or into the underlying Edmonton formation. For this reason aquifers in the Paskapoo formation

supply few wells in the eastern part of the area. Apparently the water drains out of the thin cover of Paskapoo rocks, and the main supplies come from the Edmonton beds.

The water contained in the Paskapoo formation varies greatly in quality, but generally contains much calcium carbonate, particularly if drawn from near the horizon of the siliceous limestone layers where much of the water is too hard for ordinary washing. Both above and below this zone the water may not be as hard and is soft in some cases. Most of the Paskapoo water, and particularly the very hard water, contains a noticeable amount of iron, which commonly gives yellowish or brownish stains.

Over much of the area, especially in the Edmonton formation west of Red Deer River, precautions against gas should be taken if a well is being hand dug. Boring or drilling of wells is generally advisable.

As the soft water of the area contains much soda, aluminium or magnesium casing is inadvisable in wells yielding soft water.

Township 31, Range 21. Red Deer River flows southward through the centre of the township in a valley about 400 feet deep and $1\frac{1}{2}$ miles wide. Many deep gullies, several 3 or 4 miles long, are tributary, and these cut an otherwise flattish surface. The topography is completely a reflexion of bedrock, and is unaffected by the drift.

Except for the river valley and the gullies, in which bedrock is exposed continuously, ground moraine covers the entire surface. In the northeast this has been modified by water, and patches of lake clay are present. The moraine is composed of a clayey, practically stoneless, dark, commonly almost black, till, and probably averages less than 10 feet in thickness. No wells obtain water from the unconsolidated deposits

and their thinness and clayey nature would render any attempt to do so very inadvisable.

The bedrock exposures along the river and the gullies are all of the Edmonton formation, and this formation generally underlies the unconsolidated deposits. The Paskapoo formation may be present in the higher parts of the township in the northeast and southwest, but all the water used appears to be drawn from Edmonton beds, and probably no attempt should be made to find water in the Paskapoo.

All the wells recorded are drilled, and they are from 150 to 320 feet deep, with an average depth of 210 feet. They tap aquifers lying between 2,390 and 2,590 feet elevation, and mostly from 2,440 to 2,555 feet. All yield very soft water except for one well which supplies hard water for no known reason. Iron is seldom noticeable. The water is under little pressure and has practically no rise in the wells.

The river has an immense effect on the water supply of the township, and, through its drainage of higher aquifers, is the chief cause for the deepness of the wells. This is also the reason that the supply in most of the wells in only fair, and is, in two cases, insufficient.

Several measures can be taken to ensure larger supplies of water. First, it is best to drill as far from the river valley and the deeper gullies as is possible. Second, larger supplies can be obtained by drilling nearly to river level. This would necessitate very deep drilling and probably much pumping, as the water is unlikely to have much rise. Third, the use of larger diameter holes and drilling to a greater distance below the aquifer should increase the reservoir. However, as all these measures add to expense and may not result in satisfaction, they are hardly advisable unless larger quantities of

water are absolutely necessary. Dugouts, or damming of streams and gullies, may aid in watering stock, and Red Deer River is always a potential source of water. However, anyone expecting to move into the township would be well advised to investigate water-supply conditions carefully if they anticipate requiring large quantities of water.

In general, this township is poorly off for water, and the cost of obtaining adequate supplies is high.

Township 31, Range 22. Ghostpine Creek flows southward through the centre of the township in a comparatively flat-floored valley 4 or 5 miles wide and several hundred feet deep. The elevation of the valley floor is about 2,600 feet, and from there the land rises to 2,900 feet in the northeast and 3,000 feet to the southeast. The topography reflects broad, bedrock hills whose shape is little modified by drift.

Dark, sticky, lake clay or silt covers about 20 square miles of the valley. The rest of the township is covered by a mantle of dark, commonly almost black, clayey ground moraine that contains few stones. The average thickness of the unconsolidated deposits is probably less than 15 feet. This thin sheet of drift, most of which is clay, is useless for water supply, and no well is known to draw water from it.

The Paskapoo formation is in the higher parts of the township and contains so much coarse sand that water from it can seep easily into valleys or the underlying Edmonton formation and leave it relatively dry. Thus, although the Paskapoo probably underlies much of the township, all the water used appears to come from Edmonton beds. One well 30 feet deep dug on low ground obtains a good supply of soft water. All the other wells are drilled and range from 80 to 280 feet in depth, with an average of 170 feet. The deeper wells are largely

in the high land in the northeast part of the township. Aquifers used range from 2,400 to 2,780 feet in elevation, but are mostly in that zone between 2,540 and 2,605 feet. The supply is satisfactory in all cases, and is usually good. All but four of the wells supply very soft water, but the water from two of these four is unfit for consumption. Iron in noticeable quantity is rarely present. As the water drains readily into Red Deer River it is under little pressure and has practically no rise in the wells and, consequently, requires much pumping.

Water supply is better here than in the township to the east and sufficient water for farm use can be obtained anywhere. However, large supplies, such as for town water systems or large numbers of stock, would be difficult to obtain. The deep drilling, and the large amount of pumping necessary to raise the water from its low level, make water supply here costly.

Township 31, Range 23. The divide between Threehills and Ghostpine Creeks runs through the township. The terrain in many places rises to a height of 3,000 feet above sea-level. Threehills Creek crosses the southwest corner of the township in a valley 200 feet deep and drains that part of the township, but in the east the land slopes towards Ghostpine Creek. The surface near the valleys is relatively flat, but elsewhere are coulées and broad, bedrock hills little modified by drift.

A nearly flat mantle of lake clay covers about 7 square miles along the valleys in the southwest and northeast. Sticky, clayey, grey ground moraine that contains few stones covers the remainder of the area to a depth of several feet. The unconsolidated deposits have an average thickness of less than 15 feet and are too thin and contain too much clay to be of any importance in water supply.

A thin section of Paskapoo formation underlies the unconsolidated deposits in most places, but is not thick enough to contain much water so that important amounts are also obtained from the underlying Edmonton. All wells tap bedrock aquifers and all, except one that is bored, are drilled. About half draw from each formation, but the formation used commonly cannot be determined with accuracy, as no distinct division between the formations is apparent. The wells range from 25 to 265 feet in depth, with an average of 160, and draw from aquifers between 2,600 and 2,950 feet above sea-level, and particularly between 2,600 and 2,840 feet. The lower aquifers, largely in the Edmonton formation, supply chiefly soft water, whereas the others, mainly in the Paskapoo, yield mostly hard to very hard water, which usually contains noticeable iron. Soft and hard water wells are about equal in number. Most yield adequate to good amounts of water, but in several the supply is insufficient. The wells with poor supplies are all on upper parts of gentle slopes 100 to 200 feet or more high, and thus the water tends to be drained away by springs. Deepening should greatly improve the supply in these wells, and in few cases would need to be very great. The water is under small pressure and has little rise in the wells, although its rise is greater than in the townships to the east.

In general, ample water for ordinary farm use can be obtained anywhere in the township, but large supplies might be difficult to get, because much of the water in the Paskapoo drains into valleys and seepage through the Edmonton is slow. As the wells tend to be deep, and the water-level low, drilling and pumping are expensive.

Township 31, Range 24. Threehills Creek flows southeastward across the northeast of the township in a gentle-sided valley several miles wide and as much as 200 feet deep. From the valley the surface rises both to the town of Three Hills, in the northeast, and to the

southwest, rising steeply in the very southwest corner. The topography reflects broad, bedrock features that are little modified by drift.

About 11 square miles of the valley of Threehills Creek have a flattish cover of lake clay. The remainder of the area, except for some exposures of Paskapoo formation in the west, is covered by a thin mantle of sticky, grey or black, nearly stoneless till. The unconsolidated deposits average less than 15 feet in thickness, and are too thin and contain too much clay to be a satisfactory source of water, and, indeed, none of the wells recorded draws from aquifers in them.

Paskapoo formation underlies the township, but as it is commonly too thin to contain much water the Edmonton formation is also important in water supply, and about one-third of the wells appear to use Edmonton aquifers. Wells are shallower than in the townships to the east, ranging from 30 to 250 feet in depth with an average of 110, and use aquifers between 2,620 and 2,990 feet above sea-level, with no particularly important zones in this range. Although about 60 per cent of the wells yield hard water, that from the lower, Edmonton, aquifers is generally soft, and the water has enough pressure to rise one-third to two-thirds of the distance to the surface. The quantity of water is generally adequate to good, being insufficient in only one well, which was probably a fault of the well rather than a lack of good aquifers. Iron is seldom noticeable in the water.

In general, sufficient water for farm use can be obtained at depth anywhere in the township, but much pumping is required. Wells with large supplies are not common, partly because the coarse-grained Paskapoo is easily drained to low ground, and also because the Edmonton, although containing large quantities of water, does not permit easy seepage of this water into wells as it is relatively fine grained.

Township 32, Range 21. Red Deer River flows southward, near the western edge of this township, in a valley 1 mile to 2 miles wide and more than 500 feet deep, to which many deep gullies, several as much as 3 miles long, are tributary. Except for the river valley, the gullies, and a broad, 200-foot high bedrock hill in the north, the township has a relatively flat surface.

Patches of gentle end moraine cover high land in the northeast. Elsewhere is a thin mantle of ground moraine, which in the southeast has been modified by water to give local patches of thin lake clay. The till of the ground moraine is usually dark, commonly nearly black. It is largely composed of clay and is sticky and contains few stones. As they probably average less than 15 feet in thickness, and are of a clay composition, the unconsolidated deposits are practically useless for water supply, and no wells draw from them.

Edmonton formation is exposed continuously along the river valley and in many gullies, and underlies the lower parts of the township. Paskapoo formation is probably present in much of the higher land, as in the northeast, but is much less important for water supply, and only two wells that draw from Paskapoo aquifers are recorded. These yield fair quantities of hard water that contains noticeable iron. As the Paskapoo is commonly coarse grained, water seeps quickly through it and escapes to valleys, gullies, and the underlying Edmonton. Thus, most wells must pass through the Paskapoo and tap aquifers in the Edmonton.

The wells are from 70 to 274 feet in depth, with an average of 165 feet, and use aquifers from 2,450 to 2,745 feet above sea-level, mainly from 2,525 to 2,745 feet. Those below 2,700 feet are all in the Edmonton formation, and practically all yield good quantities of very soft water without noticeable iron. Those above 2,735 feet are in the

Paskapoo. As would be expected in a township where drainage into a river valley and into gullies is strong, the water is under little pressure and has practically no rise in the wells, which makes pumping expensive. Drilling, so far as possible, from the river valley and the gullies is advisable.

Although no trouble in obtaining adequate water for farm use is apparent, difficulty may be experienced in obtaining larger quantities. More water could be obtained by drilling to about river level, or by providing larger reservoirs through larger diameter wells and by drilling deeper than the aquifer. As all these methods are expensive, the conservation and use of surface water may prove practicable if much water is required for stock.

Township 32, Range 22. The divide between Red Deer River and Ghostpine Creek strikes north through the centre of the township, and reaches 2,900 feet above sea-level. The 500 foot deep Red Deer Valley crosses the extreme northeast corner, and several of its tributary gullies cut the eastern districts. Ghostpine Creek flows southward near the western edge in a wide, gentle-walled valley 200 feet deep. Broad, bedrock hills and ridges, little modified by smaller, drift features, shape the topography.

Lake clay and silt produce a nearly flat surface in more than 12 square miles of the valley of Ghospine Creek. Elsewhere is a thin mantle of ground moraine, that increases to low end moraine in the extreme northeast, and is composed of a clayey, commonly dark or even black, sticky till that contains few stones. As the drift probably averages less than 20 feet in thickness and has a clayey composition, it is useless for water supply and no wells draw from aquifers in it.

Paskapoo formation commonly underlies the drift, but as it is thin, is in the higher areas, and is coarse grained, water easily seeps

out of itinto valleys or the underlying Edmonton. It thus has little importance in water supply, except to necessitate deeper wells where it has to be pierced. All wells recorded enter the Edmonton formation and are deep, half being more than 300 feet deep. They range from 90 to 360 feet in depth with an average of 260 feet, the deepest average of any of the townships. They tap aquifers lying between 2,370 and 2,720 feet, but largely in the zone from 2,560 to 2,625 feet above sea-level. The water in all is very soft, and iron is never noticeable. Because of drainage by springs into coulées and the nearby river valley, the water has little pressure and its rise in the wells is negligible.

Practically all the wells have ample water, but the supply is no more than adequate in four and is insufficient in one. These five wells are in the six eastern sections, near Red Deer Valley, and obviously much of their water is drained into this valley. It is advisable to drill as far as possible from the river valley, and, if large supplies are needed, it will be necessary to drill nearly to river level, although even there the amount of water available may not be as great as desired. Conservation and use of surface water may be practicable in watering many stock, and the quantity of water may be increased by having larger reservoirs in the wells, made by using larger diameter holes and going farther below the aquifers. These methods are expensive, and pumping from the low levels to which the water rises is also expensive. If much water is required conditions should be investigated carefully before moving into this township.

<u>Township 32, Range 23.</u> The Three Hills, which rise to about 3,100 feet above sea-level, are a distinctive feature of the west part of this township. Eastward from them the surface drops with a fairly uniform slope to about 2,700 feet at Ghostpine Creek, which flows southward through the east in its characteristic broad valley. The land near the creek is relatively flat, whereas elsewhere broad bedrock hills, little modified by drift, shape the topography.

Lake clay and silt, commonly not thick enough to smooth out the features of the underlying bedrock, cover about 8 square miles near the creek. A fairly smooth mantle of ground moraine, composed of sticky, usually grey, clayey, nearly stoneless till, covers the remainder of the area. As they have an average thickness of probably less than 15 feet, and are generally clayey, the unconsolidated deposits are of little importance in water supply. In section 4 one hard-water well is thought to obtain its water, an adequate supply, from these deposits.

Edmonton formation underlies the unconsolidated deposits near Ghostpine Creek, but elsewhere it is generally overlain by the Paskapoo. As the contact between the formation is uneven, difficulty arises in determining which wells draw from Paskapoo and which from Edmonton aquifers, but about two-thirds appear to enter Edmonton beds. The drilled wells are from 70 to 330 feet deep, with an average depth of 150, and tap aquifers lying between 2,595 and 2,830 feet above sea-level, and particularly in the zones of 2,595 to 2,690 feet and 2,765 to 2,832 feet. About half the wells yield soft or medium-hard water. The water from the lower aquifers tends to be softer than that from the higher, as it is drawn largely from the Edmonton formation. The water in half the wells contains noticeable iron.

The quantity of water in practically all wells is adequate to good, though in no instance is it large. The deepest well, which draws upon a low aquifer, for unknown reasons has insufficient water for ordinary farm use. The trouble may be with the well, as higher aquifers should be present. Deepening 60 feet should give a sufficient supply of soft water.

The water is under little pressure and its rise in the wells is negligible. On account of the deepness of the wells and the amount of

pumping required, water is relatively expensive to obtain in this township, and difficult to obtain in large amount.

Township 32, Range 24. In the western part of this township Threehills Creek flows southward through a gentle-walled, flattish floored valley several miles wide and perhaps 200 feet deep. From there the surface rises to Three Hills, a distinctive feature in the east. Broad bedrock hills, commonly gullied but little modified by drift, shape the topography.

A flattish mantle of lake clay and silt, that is never thick enough to smooth over the relief features of the underlying bedrock, covers about 12 square miles of the floor of Threehills Creek valley. Ground moraine, composed of a grey, sticky, usually clayey till that contains few stones, covers the remainder of the area. As the drift probably does not average much more than 15 feet in thickness, and is of a clayey composition, it is of no importance for water supply, nor, so far as is known, do any wells use aquifers in it.

Paskapoo formation underlies the drift, but is thin enough to permit the deeper wells to reach aquifers in the underlying Edmonton formation. The uneven contact between the two formations makes it difficult in some cases to determine from which formation a well draws its water. Two dug wells, one flowing, obtain good supplies of water from Paskapoo aquifers. The rest of the wells are drilled, and are from 50 to 280 feet deep with an average of 120. They tap aquifers lying between 2,675 and 2,910, but mostly from 2,735 to 2,815, feet above sea-level. All those aquifers below 2,815 feet yield, or else when the wells were new yielded, ample water. In those above 2,815 feet the supply is only fair, and from the highest aquifer insufficient. Only a few lower aquifers are in Edmonton beds, and less than one-fifth yield soft water. The water from half the wells contains a noticeable amount

of iron. The water has little pressure and its rise in the wells is in most cases negligible.

In general in this township satisfactory amounts of water, usually hard, can be obtained from aquifers below 2,815 feet. Larger amounts, such as might be needed for town supply, are probably unobtainable at any reasonable depth.

Township 33, Range 21. Red Deer River crosses the southwest corner of the township in a steep-walled valley 500 feet deep and 1½ miles wide, with several deep, tributary gullies as much as 2 miles long. From this valley edge the land rises about 200 feet towards the centre of the township. Broad, bedrock hills, with smaller ones superimposed, produce the rolling surface typical of most of the township. Many hollows in the north contain water all summer, whereas those in the south become dry, and trees, which are lacking in the south, grow in the north.

Except for 8 square miles of ground moraine in the southwest, the township has a cover of end moraine, with gentle-sloped hills that rise perhaps 20 feet above the kettles. The till composing the moraine contains much clay. It is sticky, usually brown or grey in colour, and contains few stones. The average thickness of drift is probably less than 20 feet. The ground moraine is useless for water supply, but some hard water can be obtained from end moraine, particularly from near the hollows. Two dug wells are recorded that draw fair quantities of water from it. This water would be of no importance were it not that obtaining water from the bedrock is expensive, as wells into it are deep and the rise of water negligible.

Although the Paskapoo formation underlies the unconsolidated deposits in the higher districts, it contains no water, and necessitates deep drilling in those wells that must pass through it. The lack of

water is due to the formation's relatively coarse grain-size so that, as it occupies the higher areas, the water readily drains away into valleys and the underlying Edmonton formation. All bedrock wells are drilled into the Edmonton, and are from 80 to 300 feet deep, with an average of 195. They tap aquifers between 2,530 and 2,755 feet, but mostly between 2,590 and 2,700 feet, and all yield very soft water, with iron noticeable in the water of only one well. Good quantities of water are the rule, but in several wells the supply is only adequate, and in three is insufficient. One of these latter, in the southwest of section 26, is comparatively shallow and obviously should be deeper. The lack of water in the others is more likely the fault of the wells than a lack of aquifers. Drainage into Red Deer River prevents the water having much pressure, and its rise in the wells is negligible.

In general, sufficient soft water for ordinary farm and domestic use is available in the bedrock, but larger quantities probably are unobtainable, because seepage through the fine-grained Edmonton formation is slow. Water is expensive to obtain in the township.

<u>Township 33, Range 22</u>. Red Deer River flows south in the eastern part of the township through a valley, up to 2 miles wide and 500 to 700 feet deep. This valley has many deep tributary gullies, several as long as 3 miles. It and its gully system occupies one-third of the township. The remaining two-thirds of the township consists of broad, bedrock hills and ridges, with superimposed, smaller hills in the southeast.

Low, knob-and-kettle end moraine covers about 4 square miles in the southeast, lake clay is present in the southwest, and gravel, probably pre-glacial, lies in sections 29 and 32. Otherwise the township, except for the valleys and gullies, which are mainly in bedrock, has a mantle of ground moraine composed of sticky, clayey,

usually grey, almost stoneless till. As the drift probably does not average more than 15 feet in thickness and is clayey throughout, finding a good water supply in it is impossible, and no wells draw from aquifers in it.

The Edmonton formation outcrops continuously along Red Deer Valley and in many of the gullies, and also outcrops near Ghostpine Creek in the southwest. The Paskapoo formation underlies the drift in the higher and more populated parts of the township, and supplies most of the water. Probably three-quarters of the wells draw from aquifers in the Paskapoo, but the uneven contact of it with the Edmonton makes it uncertain in which formation many aquifers are.

The water-supply conditions described for township 33, range 22, continue into that part of this township east of the river. West of the river most of the wells recorded are drilled, and range in depth from 60 to 385 feet, with an average of 135; 110 feet for those into Paskapoo and 225 feet for those into Edmonton. Aquifers used are between 2,560 and 2,860 feet above sea-level, with four wells drawing ample soft water from aquifers below 2,700 feet in Edmonton beds, but most tapping aquifers lying between 2,770 and 2,810 feet. No soft water is obtained from the Paskapoo formation, and some is very hard, too hard for washing. Half the Paskapoo wells yield water with noticeable iron, and in a few cases enough to prevent its use.

Practically all the wells in this township have good amounts of water, and the supply is inadequate in only three. One of these three, in the southeast of section 16, probably drains into Ghostpine Creek, and should need only slight deepening for improvement, whereas the other two are near Red Deer Valley and may have difficulty obtaining adequate supplies. Large amounts of water, as for town use, may also

be difficult to obtain because of drainage into Red Deer Valley. Also, because of this drainage, the water has little pressure, and generally rises no more than one-third of the distance to the surface. Wells should be drilled as far from the river as possible.

Township 33, Range 23. Ghostpine Creek flows southeastward through the centre of the township in a valley several miles wide and 150 to 250 feet deep. The land rises steadily, but gently, from the stream and, except for several gullies, reflects a generally smooth bedrock surface that has been little modified by drift.

Lake sand, silt, and clay form a flattish cover in about 13 square miles near the creek. Elsewhere a mantle of ground moraine, composed of a grey or brown, sticky, clayey, nearly stoneless till, overlies the bedrock. As the unconsolidated deposits probably do not average much more than 10 feet in thickness and are clayey, they are of no use in water supply, and no wells that draw from aquifers in them are recorded.

The Edmonton formation underlies the drift in about half the township, chiefly in a belt near Ghostpine Creek where it outcrops. The Paskapoo formation underlies the drift in the higher districts, mainly in the west and northeast, but, being comparatively coarse grained, it is easily drained into valleys and the underlying Edmonton, and thus usually is dry. The Edmonton is much more important for water supply, and practically all the wells enter it. However, as the contact of the two formations is very irregular, it is not always possible to determine in which an aquifer lies.

All the wells are drilled, and range from 55 to 300 feet in depth, with an average of 130 feet. The aquifers used lie between 2,620 and 2,830 feet elevation, but mostly between 2,665 and 2,785 feet, the lower ones mostly being in the Edmonton formation. About two-thirds of the wells yield soft water and iron is rarely noticeable.

The quantity of water is generally adequate to ample for farm and domestic use. The only well with insufficient supply went through a good, hard-water aquifer in an attempt to obtain soft water. The water generally has enough pressure to rise about one-half the distance from the aquifer to the surface, and a flowing well is present in the southwest of section 28, near Ghostpine Creek.

Red Deer Valley, although to the east of the township, even here drains the aquifers and prevents the water from rising high in the wells. Although adequate water for ordinary use is available anywhere, this drainage, a heavy run-off, and the slowness with which water seeps from the surface into the bedrock, makes it unlikely that large supplies, such as for town use, can be obtained without difficulty.

Township 33, Range 24. This township includes the divide between Ghostpine Creek and Threehills Creek. From higher than 3,000 feet above sea-level at the divide the surface drops steadily, and in the north comparatively rapidly, towards both creeks. Broad bedrock hills and ridges, in places cut by gullies, are present, but the surface is little modified by minor, drift hills. Several ponds are present, but the area is generally treeless.

Lake clay gives a flattish cover to about 4 square miles of the southwest, and a few end-moraine ridges are present, otherwise the area has a mantle of ground moraine composed of brown or grey, usually clayey but in places sandy, relatively stoneless till. As the unconsolidated deposits probably average only about 15 feet in thickness, and generally have a clayey nature, they are of little use for water supply, and none of the wells examined draws from aquifers in them.

Although the Paskapoo formation underlies the entire township, and is in places as much as 250 feet thick, the underlying Edmonton formation is also important for water supply, especially where the Paskapoo is thin. The wells are nearly equally divided between the two formations. All but one of the wells are drilled, and these range in depth from 20 to 200 feet, with an average of 100; 110 feet into Edmonton and 90 into Paskapoo. They use aquifers between 2,725 and 2,990 feet above sea-level, and particularly in the zones 2,750 to 2,830, 2,850 to 2,870, and 2,805 to 2,945 feet. Those aquifers below 2,830 feet are mostly in Edmonton beds and, except for a few between 2,750 and 2,780 feet that contain hard or very hard water with much iron, yield soft water without noticeable iron. Most aquifers above 2,850 feet yield hard to very hard water that usually contains noticeable to much iron. The thirty-four wells recorded all yield good to very good amounts of water, and supplies suitable for town use can probably be found without trouble.

As water drains away in springs along the valleys of Ghostpine and Threehills Creeks it is under little pressure and in most wells rises only about half-way to the surface. In southwest section 7, near Threehills Creek, one well flows.

Township 34, Range 21. Red Deer River flows southwestward through the northwest part of the township in a valley 2 miles wide and more than 500 feet deep. Its main tributary, Big Valley Creek, flows westward in a deep, gully like valley through the centre of the township. Large, deep gullies, a few 2 miles long, are tributary to river or creek, particularly in the north and west. The land rises southwestward, where broad, bedrock hills are overlain by small, morainal hills. The river valley and the gullies, in which the Edmonton formation is exposed continuously, occupy about 12 square miles.

Low, knob-and-kettle, end moraine, with knolls up to 20 feet high, covers about 9 square miles in the south and 2 or 3 in the north. Gravel is present in the northeast. Elsewhere the township is covered by a mantle of ground moraine, composed of sticky, clayey, brown or grey, relatively stoneless till. As the average thickness of unconsolidated deposits is probably only around 10 feet, and as they are clayey, these deposits are of little use for water supply, and none of the wells examined draws from aquifers in them.

As much as 200 feet of Paskapoo formation underlies the drift in the south and in the extreme northwest, but most of the township is underlain by Edmonton formation and the latter is more important for water supply. Water-supply conditions in township 34, range 22, hold for the small part of this township west of the river and will be described in the next section. East of the river all but one of the wells are drilled, and these range from 24 to 265 feet in depth, with an average of 130; an average of 90 feet for those into Paskapoo and 140 for those into Edmonton. Aquifers used range from 2,535 to 2,750 feet, but mostly from 2,610 to 2,710 feet above sea-level. Two wells recorded draw from Paskapoo aquifers, but the others, including all tapping lower aquifers, use those in Edmonton beds. All but two of the wells yield sufficient or ample water, and one of the two, in the southwest of section 14, had a good supply but is now partly filled with silt. As the other, in the southeast of section 16, is shallow, and is in the easily drained Paskapoo near a coulée, it could not be expected to have enough water. All the wells with only fair supplies are near coulées or the river valley.

Generally aquifers in Edmonton are better than those in Paskapoo. Sufficient water can be obtained anywhere east of the river, although difficulty may be had in obtaining large supplies. Due to the

rise of water in the wells, large reservoirs, such as are given by large-diameter wells and by drilling a distance below the aquifer, are of benefit. Although it is inadvisable to drill near deep gullies and the main river valley, it is generally easier to obtain water near this valley on the east side than on the west.

Township 34, Range 22. Red Deer River flows southwestward through the southeast corner of the township in a valley 2 miles wide and as much as 500 feet deep. Several deep gullies, a few as much as 4 miles long, are tributary to it, giving the southeast of the township a very cut-up appearance. In the west a large valley 250 feet deep and 4 miles wide strikes northward through the township. It is occupied by morainal hills and now carries no stream. The surface of the township rises to the west and southwest to more than 700 feet above river level. In the south, except for local gullies, it is smooth and reflects bedrock, whereas in the north it is broken by many morainal hills.

A thin mantle of ground moraine gives a relatively smooth surface to most of the area. Twelve square miles in the north and in the extreme southeast corner have the knolls and depressions of gentle end moraine, with hills about 10 feet high in the south but higher in the north. Small pockets of gravel are present in the west. The drift is thin, particularly in the south and near the river, and its average thickness is probably not much more than 15 feet. The till is usually clayey, grey or brown, and rarely has many stones, but the end moraine has more sand, and thus carries a fair number of trees.

As the southern part is dry and gullied and the hilly end moraine in the north is poor for farming, the township is only thinly populated and little well information is recorded. The unconsolidated deposits are too thin and contain too much clay to yield much water and all the wells

examined enter bedrock. Some poor water might, however, be obtained in the end moraine.

The Edmonton formation is continuously exposed in the river valley and in many gullies, and it underlies the large valley leading northward in the west. As much as 200 feet of Paskapoo formation underlies the higher land in the west and in the northeast, and it is a more important source of water than the Edmonton as it is present in the more populated areas. All the wells examined are drilled, and they are from 32 to 215 feet deep. The average depth is 110 feet, and most wells are around that figure. They tap aquifers between 2,540 and 2,885 feet above sea-level, but mostly in the zone from 2,755 to 2,810 feet. The aquifers above 2,660 feet, so far as can be determined, are in Paskapoo beds, and contain hard to very hard water, commonly too hard for washing. Deep wells into the Edmonton could obtain soft water anywhere. Noticeable iron, commonly enough to give a bad taste to the water, is always present. The quantity of water in practically all wells is good, and is always adequate for farm needs. As the relief in the township is considerable, the rise of water varies in different wells from negligible in some to overflowing in others and in the springs along the large valley in the western part of the township. These springs supply water in areas that otherwise would have to use Edmonton aquifers, and are in part the reason so few wells enter that formation.

Generally, good supplies of hard water are obtainable anywhere in this township. Springs are numerous, and the drilled wells are shallower and have a better rise of water than might be expected in an area so near a large river canyon.

Township 34, Range 23. Ghostpine Creek flows southeastward across the southwest corner of the township in a valley 3 miles wide and 300 feet deep. From the creek, the land rises to the southwest and northeast, and in the centre of the township is plateau like. The smooth, wide valleys and broad bedrock hills of the south are in the north covered with smaller, drift hills. Trees are common in the north, but rare in the south.

The south and west parts of the township, except for the recent sand along Ghostpine Creek, are covered by a mantle of ground moraine. The northern part, however, is covered by knob-and-kettle end moraine, with knolls 10 to 20 feet high. The till is generally brown or grey, clayey, and contains few stones, in contrast with some of the end moraine that is more sandy. The average thickness of the unconsolidated deposits is probably less than 20 feet. Two dug wells obtain hard water in the end moraine in the northeast, one obtaining a good, the other a poor, supply. Although water may be obtained in the sand along Ghostpine Creek, and elsewhere in end moraine, bedrock aquifers are more satisfactory.

The Edmonton formation probably underlies the drift near Ghostpine Creek, but elsewhere it is generally overlain by more than 200 feet of Paskapoo. The Edmonton has, therefore, little importance in water supply, although it is everywhere a potential, but deep, source of soft water. Most bedrock wells are drilled, and these are from 60 to 262 feet deep, with an average depth of 130 feet. They tap aquifers between 2,700 and 2,965 feet above sea-level, but mostly between 2,755 and 2,965 feet. The quantity of water in practically all cases is ample, and is never insufficient for ordinary farm use. The quality is mostly hard to too hard for washing and iron is noticeable in the water from two-thirds of the wells, in a few in sufficient amount to

give a bad taste to the water. The water in most wells is under insufficient pressure to have much rise, but flowing wells and springs are present.

In general, water supply is no problem in this township. Large supplies are probably most easily obtainable in the west.

Township 34, Range 24. The outstanding topographic feature of this township is the slope with which the plateau-like western half of the township drops eastward 300 feet to the valley of Ghostpine Creek. Except for several valleys tributary to this creek that cut deeply into the high land, the plateau and the creek valley have little local relief, and minor, morainal hills are not common. Several small lakes and sloughs are present, but trees are rare.

Recent sand occurs along Ghostpine Creek and some other streams. Elsewhere the township is covered by some 20 feet of ground moraine, composed of brownish, almost stoneless till, either clayey or sandy in composition. One dug well draws a fair supply of hard water from drift, and more could be found in sandy ground moraine and in sand along the streams. Generally, however, bedrock aquifers are more satisfactory.

The Edmonton formation underlies drift in places near Ghostpine Creek, but is generally overlain by 200 or 300 feet of Paskapoo. Outcrops are rare. The Paskapoo formation is more important for water supply, Edmonton aquifers being used only where the Paskapoo is thin or absent. The Edmonton is everywhere, however, a potential source of soft water for deep drilling. Several springs and some dug or bored wells tap bedrock aquifers, but most wells are drilled. The drilled wells are from 40 to 183 feet deep, with an average depth of 105 feet. Those drilled into Edmonton beds are slightly shallower than those into Paskapoo. Aquifers used lie between 2,655 and 2,950 feet above sea-level, and chiefly between 2,715 and 2,950 feet. Three quarters of the

wells yield hard or very hard water, the latter too hard for washing. The water from two-thirds of the wells contains noticeable iron, and in a few instances enough to cause an unpleasant taste. Most wells have good to very good amounts of water, the only one with insufficient supply is relatively shallow and near a valley, and could be improved by deepening. In the northwest the quantity of water, although still sufficient, does not seem as great as elsewhere in the township, probably because of easy drainage into Ghostpine Creek. The rise of water in wells on the high land of the western half is negligible, because of drainage to lower areas, whereas in the east it is very good, especially near Ghostpine Creek where springs and flowing wells occur. One well, which deserves special notice, is a 60 foot, hard-water well drilled on the road allowance in the northeast of section 23 by an oil company survey. The water rises 5 feet above surface and the flow, when examined in August 1949, was more than 75,000 gallons a day. This well drains the Paskapoo of the high land to the west.

Good or very good amounts of water can be obtained anywhere in this township, and no trouble should be encountered in obtaining sufficient for town use or other large requirements, especially from the Paskapoo of the high land in the southwest.

ANALYSES OF WELL WATERS FROM Townships 31-34, ranges 21-24, West of 4th Meridian, Alberta.

											Constituents as Analysed (parts per million)							Hardness as ($CaCO_3$) (pts. per million)		
Sample Number	¼	Section	Township	Range	Meridian	Owner	Depth of well (feet)	* Aquifer	Total dissolved solids (parts per million)	Calcium (Ca)	Magnesium (Mg)	Alkalis (Na) (K)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Bicarbonate (HCO_3)	Alkalinity (as $CaCO_3$)	Ca hardness	Mg hardness	Total hardness
3957	SW	3	33	23	4	H. Kaisler	185	E	1596	11.0	3.0	433.5	475.3	13.7	3.5	793.0	650.0	142.2	78.2	220.4
4185	NE	19	31	24	4	E.B. Thomson	30	P	1904	133.3	68.0	405.8	883.6	63	1.2	678.9	554.0	332.6	279.8	612.4
4186	NE	20	34	24	4	W.C. Malcolm	160	P	1266	90.7	177.0	61.2	360.9	NIL	1.4	822.3	574.0	226.3	723.4	954.7
4187	NE	26	33	24	4	O. Bartsch	145	E?	1016	15.5	24.0	284.2	335.2	2.2	5.3	375.3	392.8	38.7	98.8	137.5
4188	NE	23	34	24	4	Road Allowance	60	P	1616	115.0	80.8	308.4	703.7	1.4	2.7	675.9	554.0	286.9	332.5	619.4
4206	NE	24	34	23	4	G.V. Kranston	130	P?	1598	58.6	62.1	428.4	639.1	2.3	1.2	700.6	648.0	146.2	255.5	401.7
4207	NE	31	31	21	4	M. Kopjar	165	E	2498	20.6	6.6	993.6	562.1	0.7	TRACE	1878.8	1540.0	51.4	27.2	78.6
4208	NE	24	31	21	4	P. Notland	222	E	1668	22.0	10.3	646.2	117.7	19.5	7.1	1617.8	1332.0	54.9	42.4	97.3
4209	NW	16	31	23	4	L.A. Matus	120	P	2564	349.0	155.5	155.0	1177.4	20.4	30.1	600.2	492.0	870.3	557.6	1428.4
4210	SE	28	32	23	4	J. Hanna	152	E	1592	6.5	3.3	602.2	445.7	2.4	NIL	1002.8	982.0	16.2	13.6	29.8

* Symbols used for aquifers P - Paskapoo, E - Edmonton

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GEOLOGICAL SURVEY OF CANADA

WATER SUPPLY PAPER No. 312

GROUND-WATER RESOURCES OF TIGNISH MAP-AREA, PRINCE COUNTY, PRINCE EDWARD ISLAND

By

E. I. K. Pollitt

OTTAWA

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Illustrations

INTRODUCTION

This report deals with ground-water conditions of a map-area in the province of Prince Edward Island investigated by the Geological Survey of Canada during the field season of 1950.

The writer was ably assisted in the field by G. P. Williamson, A. A. McDermott, and J. I. MacDonald. All available information pertaining to the water wells in the area was recorded and water samples were taken for analyses. In addition to the regular survey, over thirty observation wells were established throughout the island. These wells were set up in July and the amount of water in each well was remeasured each subsequent month. It is hoped to repeat these measurements each year to determine any fluctuations in the ground-water table.

Thanks are here extended to the farmers throughout the area for their co-operation and willingness to supply information regarding their wells. Valuable assistance was also given by well drillers in the area, particularly Mr. Vaughan H. Groom of the Trask Well Drilling Company, Summerside.

PUBLICATION OF RESULTS

The essential information pertaining to ground-water conditions is covered in this report, which is supplied to the proper authorities. In addition, pertinent data on most of the wells will be compiled. Owing to the great number of wells, the compilation sheets will not ordinarily accompany the report. However, information regarding particular wells may be obtained from the Chief Geologist, Geological Survey of Canada, Ottawa.

With the report is a map showing the position of all wells for which records are available, together with the class of well at each location.

In order to facilitate plotting and locating wells, each lot was subdivided into areas about 1 mile square. These subdivisions were numbered vertically from north to south and lettered horizontally from west to east. Wells are numbered consecutively for each subdivision.

GLOSSARY OF TERMS USED

Alluvium. Recent deposits of clay, silt, sand, gravel, and other material deposited in lake beds and in flood plains of modern streams.

Aquifer. A porous bed, lens, pocket, or deposit of material that transmits water in sufficient quantity to satisfy pumping wells, flowing artesian wells, and springs.

Bedrock. Bedrock, as here used, refers to consolidated deposits of gravel, sand, silt, clay, or marl that are older than the glacial drift.

Contour. A line on a map passing through points that have the same elevation above sea-level.

Continental Ice-sheet. The great, broad ice-sheet that covered most of the surface of Canada many thousands of years ago.

Escarpment. A cliff or relatively steep slope separating level or gently sloping areas.

Effluent Stream. A stream that receives water from a zone of saturation.

Flood Plain. A flat part in a river valley ordinarily above water, but covered with water when the river is in flood.

Glacial Drift. A general term that includes all the loose unconsolidated materials that were deposited by the continental ice-sheet or by waters associated with it. It includes till, deposits of stratified drift, and scattered boulders and rock fragments. Several forms in which glacial drift occur are as follows:

(1) End Moraine (Recessional Moraine). A more or less discontinuous ridge or series of ridges consisting of glacial drift that was laid down by the ice at the margin of a moving ice-sheet. The surface is characterized by irregular hills and undrained basins.

(2) Ground Moraine. A widely distributed moraine consisting of glacial drift deposited at the base of an ice-sheet. The predominant material is till, which is clay containing stones. The topography may vary from flat to gently rolling.

(3) Kame Moraine. Assorted deposits of sandy and gravelly stratified drift laid down at or close to the ice margin. The topography is similar to that of an end moraine.

(4) Drumlin. A smooth oval hill that has its long axis parallel with the direction of ice movement at that place. It is composed mainly of glacial till.

(5) Esker. An irregular-crested ridge or series of discontinuous ridges of stratified drift deposited by a glacial stream that flowed beneath the continental ice-sheet. It is composed mainly of sand and gravel.

(6) Glacio-fluvial Deposits. Silt, sand, and gravel outwash, deposited by streams resulting from the melting of the ice-sheet.

(7) Glacio-lacustrine Deposits. Clay, silt, and sand deposited in glacial lakes during the retreat of the ice-sheet.

(8) Kame. An isolated mound or conical hill composed of stratified sand and gravel deposited in a crack or crevasse within the ice or in a depression along the ice front.

(9) Marine Deposits. Deposits laid down by the sea during the submergence that followed the withdrawal of the last ice-sheet. The deposits consist chiefly of clay, silt, and sand, and have emerged beaches of sand and gravel associated with them.

(10) Shoreline. A discontinuous escarpment that indicates the former margin of a glacial lake or sea. It is accompanied by scattered deposits of sand and gravel located on former beaches and bars.

Ground Water. Subsurface water in the zone of saturation below the water-table.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it was first encountered.

Influent Stream. A stream that feeds water into a zone of saturation.

Impervious or Impermeable. Beds such as fine clay or shale are considered to be impervious or impermeable when they do not permit the perceptible passage or movement of ground water.

Pervious or Permeable. Beds are pervious or permeable when they permit the perceptible passage or movement of ground water, as for example, porous sands, gravel, and sandstone.

Porosity. The porosity of a rock is its property of containing interstices or voids.

Pre-glacial Land Surface. The surface of the land as it existed before the ice-sheet covered it with drift.

Recent Deposits. Deposits that have been laid down by the agencies of water and wind since the disappearance of the continental ice-sheet; for example, alluvium in stream valleys.

Unconsolidated Deposits. The mantle or covering of loose, uncemented material overlying the bedrock. It consists of Glacial or Recent deposits of boulders, gravel, sand, silt, and clay.

Water-table. The upper limit of the part of the ground saturated with water. This may be near the surface or many feet below it. Water may be retained above the main water-table by a zone of impervious material; such water is said to be perched and its upper limit to be a perched water-table.

Wells. Holes sunk into the ground so as to obtain a supply of water. When no water is obtained they are referred to as dry holes. Wells yielding water are divided into four classes:

(1) Flowing Artesian Wells. Wells in which the water is under sufficient hydrostatic pressure to flow above the surface of the ground at the well.

(2) Non-flowing Artesian Wells. Wells in which the water is under hydrostatic pressure sufficient to raise it above the level of the aquifer, but not above the level of the ground at the well.

(3) Non-artesian Wells. Wells in which the water does not rise above the water-table or the aquifer.

(4) Intermittent Non-artesian Wells. Wells that are generally dry for a part of each year.

Zone of Saturation. The part of the ground below a water-table saturated with water.

GENERAL DISCUSSION OF GROUND WATER

Almost all the water recovered from beneath the earth's surface for both domestic and industrial uses is meteoric water, that is, water derived from the atmosphere. Most of this water reaches the surface as rain or snow. Part of it is carried off by streams, part evaporates either directly from the surface and from the upper mantle of soil or indirectly through transpiration of plants, the remainder infiltrates into the ground to be added to the ground-water supplies.

The proportion of the total precipitation that infiltrates from the surface into the zone of saturation will depend upon the surface topography and the type of soil or surface rock. More water will be absorbed in sandy or gravelly areas, for example, than in those covered with clay. Surface run-off will be greater in hilly areas than in those that are relatively flat. In sandy regions where the relief is great, the first precipitation is absorbed and run-off only commences after continuous heavy rains. Light, continued precipitation will normally furnish more water to the underground supply than brief torrential floods, during which the run-off will nearly equal the precipitation. Frozen soil is quite impermeable and moisture falling upon it will not usually find its way below the surface. Accordingly, during the winter, very little water reaches the zone of saturation. Light rains falling upon the surface of the earth during the growing season may be wholly absorbed by growing plants. The quantity of moisture lost through direct evaporation depends largely upon temperature, wind, and humidity. Ground water in areas overlain by pervious material may be recharged by influent streams carrying run-off from areas overlain by relatively impervious material.

The average monthly and annual precipitation (in inches) at Charlottetown, Hamilton, and Summerside, observed over periods of 65, 16, and 18 years respectively is as follows:[1]

[1] Data from "Climatic Summaries for Selected Meteorological Stations in the Dominion of Canada", Vol. I, Meteorological Division, Department of Transport, Canada.

	Yrs. obs.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
C.	65	3.76	3.01	3.15	2.78	2.66	2.58	2.98	3.35	3.40	4.07	3.75	3.98	39.47
H.	16	3.03	2.60	3.75	3.27	2.52	2.60	2.94	3.45	3.12	3.12	3.75	2.97	37.12
S.	18	2.68	3.11	3.10	2.75	2.86	2.77	3.62	3.59	3.32	3.36	3.70	3.80	38.66

C.-- Charlottetown; H.-- Hamilton; S.-- Summerside.

If Summerside is used as an example and it is borne in mind that a layer of water 1 inch deep over an area of 1 square mile amounts to approximately 14,520,000 imperial gallons, it will be seen that an average of 561,343,200 imperial gallons of water fall on each square mile in the Summerside area in 1 year. Although it would not be possible to determine the annual recharge of the ground-water supply of the area, if it were assumed that only 10 per cent of the total precipitation reached the zone of saturation, it will be seen that the annual recharge for 1 square mile would be

5,613,432 gallons. If there is a daily consumption of 200 gallons per farm and 35 gallons per person in the communities, an estimate of the total consumption for Tignish map-area (200 square miles) shows it to be only 10 per cent of the estimated annual recharge. If, on the other hand, 360 gallons per farm are consumed as well as 60 gallons per person in the communities, then 17 per cent of the recharge is used annually. It seems reasonable to conclude that precipitation is adequate to furnish supplies of ground-water for Tignish map-area and possibly the entire province.

The monthly and annual precipitation from 1947 to 1950 at meteorological stations within the area is given on page 6.

In most regions of the world where precipitation is effective there is an underground horizon known as the ground-water level or "water-table", which is the upper surface of the zone of water saturation. The water that enters from the surface into the rocks of the earth is drawn down by gravity to where it either reaches the zone of saturation or comes in contact with a relatively impervious layer of rock. Such a layer may stop further downward percolation, resulting in perched water and creating a perched water-table. If a water-table is at or near the surface there will be a lake or swamp, if it is cut by a valley there will be a stream in the valley. The terms "influent" and "effluent" are used with reference to streams and their relation to the water-table. An influent stream feeds water into a zone of saturation and an effluent stream receives water from a zone of saturation. The ground water in the zone of saturation is almost constantly on the move, percolating toward some point of discharge, which may be a spring or a pumping well.

All rocks and soils are to some degree porous, that is, the individual grains or particles of which they are composed are partly surrounded by minute interstices or open spaces that form the receptacles and conduits of ground water. In most rocks and soils the interstices are connected and large enough for the water to move from one opening to another. In some rocks or soils, however, they are largely isolated or are too small for the water to percolate. The porosity of a material varies directly with the size and number of its interstices, which in turn depend chiefly upon the shape and arrangement and the degree of assortment of the constituent particles. A fine-grained rock such as shale, limestone, or dolomite may have such small interstices that the contained water will not flow readily and wells penetrating them may derive little or no water. Such rocks are considered impervious. More coarse-grained materials such as sand, gravel, or sandstone readily yield their water to wells and are called water-bearing beds or aquifers. A clean water-bearing gravel constitutes one of the best sources of water. This is true whether the water is derived from the zone of saturation or from a bed of gravel confined between or below beds of more impervious material.

PRECIPITATION IN INCHES AT VARIOUS OBSERVATION STATIONS[1]

Station	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Allison	1947	1.0	2.4	1.5	2.9	5.6	4.2	2.6	0.5	4.3	1.3	1.8	3.5	31.6
	1948	2.8	1.4	1.8	2.4	2.8	2.0	1.8	1.7	2.2	0.7	-	1.9	--
	1949	1.9	1.8	3.1	2.6	1.1	1.5	1.8	4.1	2.1	1.6	4.0	1.0	26.6
	1950	2.7	2.5	2.0	1.6	0.6	1.1	2.1	3.1	1.1	2.1	1.5	1.9	22.3
Charlottetown	1947	4.0	3.1	2.2	4.1	5.8	5.2	2.6	1.3	4.7	1.2	4.5	4.7	43.4
	1948	2.8	2.0	2.6	3.2	3.5	3.1	3.[illegible]	3.4	3.7	3.2	5.6	3.7	41.2
	1949	3.2	4.3	4.5	3.3	2.5	2.8	1.7	4.2	4.5	2.3	4.3	2.8	40.4
	1950	3.5	3.2	1.9	2.6	1.0	2.4	3.2	6.9	1.0	2.4	3.5	3.9	35.5
Charlottetown Airport	1947	-	-	-	3.4	5.8	5.0	2.5	1.3	5.1	1.1	4.5	3.4	--
	1948	2.8	1.6	2.4	3.5	3.8	3.2	3.5	3.2	3.5	-	5.6	3.2	--
	1949	2.5	4.2	5.7	4.2	2.9	2.0	2.1	5.0	4.4	2.2	4.4	2.9	42.5
	1950	3.3	2.7	1.4	3.8	0.9	2.3	3.9	6.7	0.9	2.5	4.4	4.9	37.7
Ellerslie	1947	3.6	4.5	1.5	3.3	3.6	5.1	1.4	1.9	4.8	-	3.0	-	--
	1948	-	1.9	1.4	1.9	-	4.7	3.2	3.5	2.6	2.0	5.4	3.0	--
	1949	2.9	3.0	7.2	3.2	2.4	4.1	-	-	4.6	-	-	2.1	
	1950	3.0	5.1	2.2	3.1	0.7	3.8	5.0	-	-	3.0	5.2	4.8	--
Summerside	1947	3.5	3.3	1.8	2.9	3.6	5.1	1.8	1.7	4.0	2.1	3.3	3.3	36.4
	1948	3.0	1.5	1.8	2.8	3.0	4.1	4.9	6.4	3.0	2.2	3.7	2.6	39.0
	1949	2.5	4.1	4.8	3.0	2.9	3.4	2.0	3.6	4.5	1.8	4.4	2.6	39.6
	1950	2.8	4.4	2.1	3.8	0.8	3.6	4.1	5.6	0.3	2.5	5.5	5.4	40.9
Summerside Airport	1947	2.5	3.1	1.5	2.4	3.5	4.4	1.1	2.0	4.0	2.2	2.8	2.8	32.3
	1948	-	-	-	-	3.3	4.3	4.9	6.3	3.1	2.4	-	2.9	--
	1949	2.2	4.5	4.3	3.6	3.2	3.0	1.9	3.2	4.7	2.1	4.5	3.1	40.3
	1950	3.1	3.5	2.4	2.3	0.7	3.6	4.0	4.8	1.4	2.6	5.0	4.6	38.0

[1]Extracts from the Monthly Weather Map, Meteorological Service, Dominion of Canada.

The most common wells and those that in drift-covered areas yield the largest aggregate supply of ground water are water-table wells, that is, they derive their water from the zone of saturation. Many shallow water-table wells become dry during the late summer, winter, or periods of extreme drought. In most cases this is due to the lowering of the water-table below the bottom of the well. The grouping together of a number of water-table wells within a limited area will also lower the yield of any one of the wells. This is especially true if the water-producing formations are of low permeability. When a well penetrates an aquifer confined by impervious beds, water flowing under pressure will rise in the well to a level equivalent to the hydrostatic pressure exerted at the point of its entrance into the aquifer. If the hydrostatic pressure is great enough to force the water to the surface, a flowing artesian well is formed.

Springs are formed by the water-table, or some aquifer containing water, outcropping at the surface of the ground. The water emerging from water-table springs is free water flowing down the gradient of the water-table. In many cases these springs occur as slow seeps along the lower edges of stream valleys. A large number in one area could maintain a swamp. A group of artesian springs occurring in one area could provide sufficient water to maintain a lake or form the source of a stream.

GENERAL DISCUSSION OF GROUND-WATER ANALYSES

The mineral content of ground water is of interest not only to consumers but also to industries seeking water of specific quality. Both the kind and quantity of mineral matter dissolved in a natural water depend upon the texture and chemical composition of the rocks with which the water has been in contact. Pollution is caused by contact with organic matter or its decomposition products. Analyses of well waters for mineral content are made by the Bureau of Mines, Department of Mines and Technical Surveys, Ottawa.

In any given area, an attempt is made to secure samples representative of the waters of all main aquifers. The quantities of the various constituents for which tests are made are given as "parts per million", which refers to the proportion by weight of each constituent in 1,000,000 parts of water.

The following mineral constituents include all that are commonly found in natural waters in quantities sufficient to have any practical effect on the value of the waters for ordinary uses.

Silica (SiO_2) may be derived from the solution of almost any rock-forming silicate, although its chief source is from the feldspars. It is commonly determined in the analyses of water for use in steam boilers, as silica is classed as an objectionable encrustant.

Calcium (Ca) is derived originally to a great extent, from the decomposition of lime feldspars. The chief sources of calcium dissolved in ground water are from the solution of limestone, gypsum, and dolomite. The common compounds of calcium are calcium carbonate ($CaCO_3$) and calcium sulphate ($CaSO_4$), neither of which has injurious effects upon the consumer, but both of which cause hardness. Calcium carbonate is active in the formation of boiler scale.

Magnesium (Mg) is derived originally from many igneous rocks although its chief source for ground water is dolomite, a carbonate of calcium and magnesium. The sulphate of magnesium ($MgSO_4$) combines with water to form "Epsom salts" and renders the water unwholesome if present in large amounts.

Sodium (Na) is found in all natural waters in various combinations, although its salts constitute only a small part of the total dissolved mineral matter in most waters in humid regions. Sodium salts may be present as a result of pollution by sewage or of contamination by sea water, either directly or with that enclosed in marine sediments. Moderate quantities of these constituents have little effect upon the suitability of a water for ordinary uses, but water containing sodium in excess of about 100 parts per million may require careful operation of steam boilers to prevent foaming. Waters containing large quantities of sodium salts are injurious to crops and are, therefore, unfit for irrigation. The quantity of sodium salts may be so large as to render a water unfit for nearly all uses.

Potassium (K), like sodium, is derived originally from the alkaline feldspars and micas. It is of minor significance and is sometimes included with sodium in chemical analyses.

Iron (Fe) is almost invariably present in well waters, but rarely in large amounts. It is dissolved in combination from many rocks as well as from iron sulphide deposits with which ground water comes in contact. It may also be dissolved from well casings, water pipes, and other fixtures in quantities large enough to be objectionable. Upon exposure of the water to the atmosphere the iron separates as the hydrated oxide causes a yellowish brown discoloration. Excessive iron in water causes staining on porcelain or enamelled ware and renders the water unsuitable for laundry purposes. Water is not considered potable if the iron content is more than 0.5 part per million.

Sulphates (SO_4). Deposits of gypsum constitute the principal source of sulphates dissolved in ground water. They occur chiefly as the salts of calcium, magnesium, and sodium. Sulphates cause permanent hardness in water and aid in the formation of injurious boiler scale. Sodium and magnesium sulphates are laxative when present in quantities of more than 900 parts per million.

Chloride (Cl) is nearly all either of organic origin or derived from marine rocks and sediments. It occurs usually as sodium chloride and less commonly as calcium chloride and magnesium chloride. Sodium chloride is a characteristic constituent of sewage, and any locally abnormal quantity in ground water suggests pollution from this source. However, in view of the many sources from which chlorides may be derived, such abnormal quantities should not, in themselves, be taken as positive proof of pollution. Chlorides impart a salty taste to water if present much in excess of 300 parts per million.

Nitrates (NO_3) are of minor importance in the study of ground water. Relatively large quantities in a water may represent pollution by sewage, or drainage from barnyards, or even fertilized fields. It is recommended that a bacteriological test be made of water showing an appreciable nitrate content if it is to be used for domestic purposes.

Carbonate (CO_3) forms a large percentage of the solid compounds held in solution by the average ground water. The two chief sources are the decomposition of feldspars and the solution of limestone. Water carrying carbonic acid in solution is the primary agent in rock decomposition. Carbonates are indicated in the table of analyses as alkalinity. Calcium and magnesium carbonate cause hardness in water, whereas sodium carbonate causes softness.

Bicarbonate (HCO_3). Carbon dioxide dissolved in water renders the insoluble calcium and magnesium carbonates soluble as bicarbonates. The latter are decomposed by boiling the water, which changes them into insoluble carbonates that form a coating on the inside of cooking utensils.

Total Dissolved Solids (Residue on Evaporation). The term 'total dissolved solids' is applied to the residue obtained when a sample of water is evaporated to dryness. Waters are considered high in dissolved mineral solids when they contain more than 500 parts per million, but may be accepted for domestic use up to that point if no better supply is available. Residents accustomed to the waters may use those that carry much more than 1,000 parts per million of total dissolved solids without inconvenience, although persons not used to highly mineralized waters would find them objectionable.

Hardness is a condition imparted to waters chiefly by dissolved calcium and magnesium compounds. It here refers to the amount of soap that must first be used to precipitate the above compounds before a lather is produced. The hardness of water in its original state is its total hardness, and is classified as 'permanent hardness' and 'temporary hardness'. Permanent hardness remains after the water has been boiled. It is caused by mineral salts that cannot be removed from solution by boiling, but it can be reduced by treating the water with natural softeners, such as ammonia or sodium carbonate, or with many manufactured softeners. Temporary hardness can be eliminated by boiling and is due to the presence of bicarbonates of calcium and magnesium. Waters containing larger quantities of sodium carbonate than calcium and magnesium compounds are soft, but if the latter compounds are more abundant the water is hard. The following table[1] may be used to indicate

[1] Thresh, J.C., and Beale, J.F.: The Examination of Waters and Water Supplies; London, 1925, p. 21.

the degree of hardness of a water:

Total Hardness Parts per Million	Character
0 - 50	Very soft
50 - 100	Moderately soft
100 - 150	Slightly hard
150 - 200	Moderately hard
200 - 300	Hard
300 - and over	Very hard

TIGNISH MAP-AREA, PRINCE COUNTY, PRINCE EDWARD ISLAND

Physical Features

Tignish map-area is located in the west part of Prince county at the extreme northwest end of Prince Edward Island. It has an area of 200 square miles. The towns of Alberton and Tignish, the largest of several small communities within the area, are 90 and 100 miles respectively northwest of the capital city of Charlottetown.

The surface of Tignish map-area is relatively flat. A gently undulating to rolling effect in some parts is due chiefly to downcutting by streams since the retreat of the ice rather than to glaciation.

The shoreline bordering the map-area shows evidence of both emergence and submergence. The west shore is characteristic of an emergent shoreline whereas the east shore shows stages of both emergence and submergence. Offshore bars are a feature of the southeast shoreline.

A prominent topographic feature is a series of discontinuous ridges or bluffs that roughly parallel the present shoreline, particularly the west shoreline, and can be traced intermittently throughout the map-area. These bluffs represent emerged marine shorelines. In general they follow the 25, 50, and 75-foot contours.

Surface elevations increase gradually from sea-level to a maximum of approximately 180 feet in the central part of the area.

The area is drained mainly by Miminegash, Tignish, Little Tignish, Kildare, Huntley, and Mill Rivers, as well as by numerous small creeks. Miminegash River, together with a number of smaller creeks, flows westerly into Northumberland Strait. Tignish and Little Tignish Rivers drain an area immediately south of the town of Tignish. Kildare River and its tributary Huntley River flow southwesterly across the eastern part of the area. Mill River flows easterly into Cascumpeque Bay, south of Alberton. The source of much of the water in the rivers and creeks along the west shore is in the wooded and swampy areas underlain by relatively impervious clay till. Springs form a source of the water in other rivers. A few springs, some of which issue from sandstone, are scattered along stream valleys. Some streams have been dammed, and are utilized to operate small sawmills. However, as more land is cleared and swamps drained, many of the permanent streams will become intermittent, and it will become increasingly difficult to operate such industries.

GEOLOGY AND WATER SUPPLY

Bedrock Formations and Their Water-bearing Properties

The entire province of Prince Edward Island is underlain by Upper Carboniferous or possibly Permian formations. They consist of soft, dark red sandstone, soft, thin-bedded, red shale, hard pebble-conglomerate, and irregular beds of impure limestone containing pebbles of bright red shale. These latter

are described locally as limy conglomerates.

Sandstone, because of its relatively high porosity, constitutes the most satisfactory bedrock source of ground water. E. D. Ingall[1] notes that in most instances ground water was

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[1] Ingall, E. D.: Boring on Prince Edward Island; Geol. Surv., Canada, Sum. Rept. 1909, p. 30.

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encountered in sandstone during the drilling of five deep holes under the direction of the Geological Survey of Canada in 1908-9. Where sandstone was located under beds of less permeable shale, the water was sometimes under pressure and rose a considerable distance in the well. The greatest depth at which fresh water was encountered in these holes was at 1,560 feet in well No. 4, $1\frac{1}{4}$ miles from Little Sands, Kings county. Below the fresh water horizons, the water was increasingly brackish and finally quite saline. In holes drilled adjacent to the sea-coast, the water encountered rose in the casing to an elevation corresponding to that of the sea water, and the rise and fall of the tides produced a direct effect upon it.

Although soft, red shales are not a satisfactory source of ground water in themselves, their location in bedrock suggests the possible presence of aquifers containing ground water under pressure as ground water located beneath such a shale bed will generally rise a considerable distance in the well from the point where it was first encountered. The presence of impermeable shale beds near the surface may result in the creation of perched water-tables. Because of the limited extent of these shale beds, shallow wells deriving their water from above the shale in such localities are not satisfactory and will go dry rapidly during drought.

Beds of limestone and conglomerate are not extensive and are unimportant as sources of ground water. Their relative impermeability causes them to behave like the shale beds in that ground water occurring immediately below is under pressure and will rise in the well when encountered.

Tignish map-area is well supplied with ground water for both domestic and stock purposes. Over 87 per cent of the wells in the area are bored and 66 per cent obtain their water from depths of 40 feet or less. A survey of the well records show that 97.5 per cent of the wells have a permanent water supply. The chief sources of ground water in Tignish map-area are bedrock formations, and of these sandstone only is of any importance. Of the 1,809 wells and springs in the area 49 per cent are known to have their aquifers in sandstone. Although the character of the bedrock in 46 per cent of the wells is unknown, it is, without doubt, sandstone as no other type of bedrock was found to be a favourable source of ground water. The term "unknown" is used when the owner was unable to supply information regarding the character of the aquifer, or when the well was bored during a previous owner's occupancy. The information regarding the character of the aquifer was derived solely from the statements of the owners and the drillers.

One of the five deep holes mentioned previously was drilled on the west shore of the map-area, $1\frac{1}{2}$ miles north of

Miminegash. The various aquifers (heavy flows) are listed in the following commentary by E. D. Ingall:[1]

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[1] Ingall, E. D.: Boring on Prince Edward Island; Geol. Surv., Canada, Sum. Rept. 1909, p. 30.

"Fresh water was encountered in the hole at 230 feet; a very heavy flow, which rose to within 30 feet of the surface. At 460 feet a very heavy flow of fresh water was again encountered, the previous flow having been cased off. This water finally rose to tide level. At 620 feet the water began to get brackish. At 871 feet the water was cased off and a heavy flow of salt water was encountered at 960 feet, which rose to sea-level when the boring attained a depth of 1,020 feet. The upper water was cased off at 1,279 feet, but another heavy flow of salt water was met with at 1,350 feet, which by the time 1,470 feet of depth had been attained had risen to sea-level. At 1,470 feet the upper water was again cased off, but a further supply of very salt water was met with at 1,480 feet, rising to within 100 feet of the surface. This was cased off at 1,562 feet.

"Great difficulty was met with throughout the operations due to the heavy flow of water and the constant caving of the brown shales where encountered, and the difficulty of drilling in this class of rock when the hole was full of water."

This well attained a depth of 1,670 feet. From the above commentary, the heavy flows of water encountered at various depths may be noted and also the height to which the water rose in each case. Eventually salt water found its way into the bore-hole and successive aquifers all contained salt. It was mentioned that fresh water was encountered at 230 feet. This does not mean it was the first water to appear in the hole, as shown by the following two examples:

1. An open well was dug to a depth of 3 or 4 feet close to the bore-hole and all the water needed by the drilling machine was supplied by this shallow well.

2. On the farm adjoining the bore-hole the total water supply is obtained from a spring issuing from marine sand.

Only one drilled well, located near the wharf at Tignish Shore, resulted in a flowing-artesian supply. This well was drilled to a depth of 327 feet in 1942. The greatest height to which the water rose was 4 feet above the surface of the ground at the time the well was drilled, but at the present time the water rises only 1 foot above the surface. The yield is only ½ gallon per minute and the tides have a direct effect upon the hydrostatic pressure and the resulting rate of flow; a high tide causing an increase in pressure and a low tide a decrease.

In the case of bored wells, sandstone is also the principal aquifer. In boring wells it is necessary in many cases to drill through the limy conglomerate or the pebble-conglomerate before a satisfactory supply of water is obtained. Many owners report that after the drill has penetrated a layer of hard rock it drops from 3 to 6 inches into water. According to information received from well drillers the apparent "drop" is the result of the hand drill passing through the relatively hard pebble-conglomerate or limy conglomerate into the softer

sandstone. The contrast between the different types of rock is all the more apparent if the sandstone is saturated with water.

A few wells are dug through the overlying unconsolidated deposits to sandstone, from which water is obtained. Most of these wells are shallow, as the sandstone is fairly close to the surface and lies directly below the surface deposits without any intervening shale or conglomerate zones.

Springs generally occur where porous lenses or beds are exposed by natural slopes, cliff faces, or stream valleys. Some springs used for domestic and stock purposes obtain their water from sandstone. The best illustration of bedrock springs is to be found along the cliffs of the present shoreline. Here the water seeps downward through porous layers of rock until some impervious shale zone is reached. The water then flows along the top of the shale layer, following the hydraulic gradient, and issues at the face of the cliff. Some of these springs are under sufficient hydrostatic pressure to flow as steady streams from the rock, but most are merely slow seeps where the water-table outcrops at the surface.

Unconsolidated Deposits and Their Water-bearing Properties

During the Pleistocene or glacial epoch, great accumulations of ice formed at one or more centres in northern Canada. This ice moved out in all directions and covered large regions with what has been called the Continental Ice-sheet. As the ice advanced, it picked up, transported, and redeposited great quantities of loose rock debris. This material is unconsolidated and is commonly called glacial drift. The ice-sheet advanced and retreated several times and after each retreat left an accumulation of drift on the surface over which it had passed. This drift, together with dune sand, stream flood plain deposits of alluvium, and swamp deposits of muck and peat, constitute, to a large extent, the unconsolidated deposits on the Island.

Most of the glacial drift consists of boulders and pebbles of various sizes, some foreign, but predominantly of Island bedrock, embedded in a matrix of clay or sandy clay. This material is known as a till. The following are the more important types of unconsolidated deposits with their water-bearing properties that occur in Tignish map-area: (1) glacial deposits; (2) marine deposits; (3) marine beach deposits; (4) glacio-fluvial deposits; (5) recent deposits, consisting of beach sand and gravel, dune sand, stream alluvium, and muck and pent.

Only 5 per cent of the total number of wells obtain their water from these unconsolidated deposits.

Glacial Deposits. This type consists of glacial drift varying chiefly from a clay till to a sandy till in different parts of the area. Gravelly, sandy till is not extensive and is not an important source of ground water. Although the zone of saturation with its accompanying water-table exists in clay till, the interstices in the till are extremely small and much of the contained water is not recoverable by wells. Swamp conditions are common in clay till areas. Sandy till yields a more satisfactory supply of water, but is not sufficiently extensive in the area to form an important source. No wells were

found to draw their water solely from the glacial deposits.

Marine and Marine Beach Deposits. These deposits consist chiefly of silt, sand, and gravel. They are very porous and yield their water freely to shallow dug wells. Perched water, although not common, is present in these areas. Such localities cannot be expected to yield a satisfactory supply of ground water unless the well passes through the perched zone and enters the true zone of saturation. There are no drilled or bored wells in these marine deposits. All dug wells are shallow, but the yield of those used as the sole source of water supply of a farm is fairly consistent. Almost 4 per cent of the total number of wells obtain their water from these deposits.

Glaciol-fluvial and Alluvial Deposits are of relatively small extent and, although they consist of well stratified silt, sand, and gravel that are very porous and should yield good supplies of water, do not constitute important sources of ground water.

Dune sand deposits are very porous and should yield satisfactory supplies of ground water to wells that penetrate the water-table. They provide the water supply for half the wells in the fishing community of Miminegash, from shallow dug wells. Although the supply is not great, as some families are partly dependent upon deeper bored wells for their needs, the water level appears to remain fairly constant and no well is known to become intermittent. The ground water in the dug wells comes from a perched zone above the true zone of saturation.

Many of the dug wells have a small water supply and are used solely for refrigeration purposes. Most of the intermittent wells are of this type.

The possibilities of obtaining flowing-artesian wells in Tignish map-area are not good. The porous sandstone beds as well as the deposits of Pleistocene marine sand and gravel provide an excellent intake area for ground water, but the relief is so slight there is very little possibility of the ground water eventually returning to the surface at lower elevations in flowing-artesian wells.

Springs are numerous throughout the area, but only those springs are shown on the map which constitute the sole source of water supply of a farm. All but one of the 38 listed are found in the unconsolidated sand and gravel deposits, and of this number 28 are located in the marine deposits.

WATER SUPPLY OF THE TOWNS OF ALBERTON AND TIGNISH AND OTHER COMMUNITIES

All communities in Tignish map-area obtain their water from privately owned wells. With the exception of half the wells in Miminegash the supply comes mainly from sandstone. Nearly all wells have a permanent supply of water.

Alberton

In Alberton, the largest of all the communities, one hundred and thirty-one wells were surveyed. All but two of these wells are of the bored type. Over 64 per cent obtain their water from depths of from 21 to 40 feet. All known aquifers are sandstone, and although the aquifer is not listed for forty-nine wells, it is presumed also to be sandstone. The average depth of unconsolidated material in Alberton is 7 feet.

Alberton South

Forty-four wells were surveyed in Alberton South. All but three are bored, and almost 80 per cent obtain their water from depths of from 21 to 40 feet. All but one of the known aquifers are sandstone. One family is supplied by a spring. The average depth to bedrock in Alberton South is 4 feet.

Tignish

Tignish, the second largest of all the communities, has ninety-six wells, ninety-one of which are of the bored type. Over 57 per cent obtain their water from depths of from 21 to 40 feet. All known aquifers are sandstone, and although the aquifer is not listed for fifty-seven wells, it is presumed also to be sandstone. The average depth of unconsolidated material is 9 feet in Tignish.

Tignish Shore

There are twenty-eight wells in Tignish Shore. Two of this number have been drilled, the remainder bored. One of the drilled wells produced a flowing-artesian supply used by ten families. Over 71 per cent of the wells obtain their water from depths of from 21 to 40 feet. All known aquifers are sandstone. The average depth to bedrock in Tignish Shore is 10 feet.

St. Louis

Thirty-three wells were surveyed in St. Louis. All wells are of the bored type and almost 67 per cent obtain their water from depths of from 21 to 40 feet. All known aquifers are sandstone. The average depth to bedrock in St. Louis is 9 feet.

Elmsdale

Elmsdale has twenty-three wells and all are bored. All but one obtain their water from depths of from 21 to 40 feet. All known aquifers are sandstone. The average depth to bedrock is 12 feet.

Miminegash

Miminegash has nineteen wells. Nine are bored, nine dug, and one drilled. All dug wells obtain their water from

depths of 20 feet or less and almost all the others receive their water from depths of from 41 to 60 feet. In six the aquifers are known to be sandstone and in four presumed also to be sandstone. The dug wells obtain their water from recent dune sand.

Bloomfield

There are thirteen wells in Bloomfield and all are of the bored type. All but one obtain their water from depths of from 21 to 40 feet. All known aquifers are sandstone, and although the aquifer is not listed for eight wells, it is presumed also to be sandstone.

ANALYSES OF WATER SAMPLES

Thirty-six samples of well waters from Tignish map-area were analysed for their mineral content by the Bureau of Mines. The samples were taken from depths of 0 foot to 327 feet, and nearly all are from sandstone. All waters were found to be suitable for domestic and farm use.

Amounts (in parts per million) of dissolved mineral matter in waters collected in Tignish map-area:

Constituent	Quantity		
	Maximum	Average	Minimum
Total dissolved solids...........	666.0	221.2	86.0
Silica..........................	17.0	7.4	1.2
Calcium.........................	101.0	34.4	8.2
Magnesium.......................	22.5	8.9	0.2
Alkalis (sodium and potassium)...	169.9	24.7	6.4
Sulphate........................	161.0	18.5	3.3
Chloride........................	101.0	29.7	7.2
Nitrate.........................	76.4	15.3	0.0
Bicarbonate.....................	330.0	117.3	35.6
Total hardness..................	303.4	122.2	28.3

CONCLUSIONS

This investigation warrants the following conclusions:

(1) Ground-water supplies of Tignish map-area are abundant for domestic, stock, and field uses. Most farms have wells in their pastures and potato fields, which supplement the water supply for cattle as well as providing an adequate supply for irrigation of field crops.

(2) Precipitation appears sufficient to ensure adequate supplies of ground water.

(3) The chief source of ground water is sandstone. The sandstone is soft and allows penetration by hand drills. In

order to reach water in sandstone, it is often necessary to bore through overlying, hard, limy conglomerate and (or) pebble-conglomerate.

(4) Marine sands and gravels provide water for a number of dug wells.

(5) Dune sand deposits provide a water supply for half the wells in the community of Miminegash.

(6) No suitable aquifers for ground water are present in glacial till.

(7) Although one flowing-artesian well is found within the map-area, conditions that produce this type of well are not likely to exist.

(8) All villages and communities in Tignish map-area have an abundant and permanent water supply.

(9) The quality of ground water derived from sandstone is quite suitable for domestic and farm use.

(10) The presence of large forested areas are of vital importance in maintaining a sufficient supply of ground water. It was noted that the forests in the map-area are gradually being depleted and very little effort is being made toward reforestation. It is suggested that wherever possible some plan of reforestation be carried out. This would undoubtedly ensure an abundant supply of ground water for the future.

TIGNISH MAP-AREA

Summary of Wells and Springs Used as a Source of Water Supply

Wells and Springs	LOTS							COMMUNITIES								Total No.	Per cent
	1	2	3	4	5	6	7	A	As	T	Ts	SL	E	M	B	in area	of total
Total number	403	291	226	317	149	1	35	131	44	96	28	33	23	19	13	1809	
Bored	331	256	194	272	136	1	25	129	41	91	26	33	23	9	13	1580	87.3
Dug	55	27	20	29	11	0	7	1	2	2	0	0	0	9	0	163	9.0
Drilled	4	1	3	10	2	0	1	1	0	3	2	0	0	1	0	28	1.6
Springs	13	7	9	6	0	0	2	0	1	0	0	0	0	0	0	38	2.1
Wells 0-20 feet deep	100	45	35	40	11	0	10	3	3	7	1	1	0	9	0	265	14.7
21-40	190	152	108	161	60	1	11	84	36	55	20	22	22	2	12	936	51.7
41-60	86	78	47	83	50	0	9	38	5	28	3	8	1	7	1	444	24.6
61-80	15	15	28	24	21	0	5	4	0	4	2	2	0	0	0	120	6.6
81-100	9	1	8	8	7	0	0	2	0	1	0	0	0	1	0	37	2.0
101-120	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	3	0.2
over 120	2	0	0	0	0	0	0	0	0	1	1	0	0	0	0	4	0.2
Wells that yield hard water	153	124	147	204	66	0	24	59	16	46	9	17	15	3	8	891	49.2
Soft	249	167	79	113	83	1	11	72	28	49	19	16	8	15	5	915	50.6
Salty	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	3	0.2
Wells with aquifer in sandstone	176	146	85	168	88	1	16	82	20	39	19	21	17	6	5	889	49.1
In marine sand or gravel	25	10	15	13	0	0	6	0	1	0	0	0	0	0	0	70	3.9
In recent sand	3	2	2	1	0	0	0	0	0	0	0	0	0	9	0	17	0.9
Unknown	199	133	124	135	61	0	13	49	23	57	9	12	6	4	8	833	46.1
Flowing-artesian wells	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0.1
Non-flowing artesian wells	4	1	3	10	2	0	1	1	0	3	2	0	0	1	0	28	1.6
Non-artesian wells	386	283	214	301	147	1	32	130	43	93	25	33	23	18	13	1742	96.2
Springs	13	7	9	6	0	0	2	0	1	0	0	0	0	0	0	38	2.1
Wells with permanent supply	390	284	219	306	144	1	35	131	44	95	28	33	23	18	13	1764	97.5
Wells with non-permanent supply	13	7	7	11	5	0	0	0	0	1	0	0	0	1	0	45	2.5

A -- Alberton　　T - Tignish　　SL - St. Louis　　M - Miminegash

As - Alberton South　　Ts - Tignish Shore　　E - Elmsdale　　B - Bloomfield

ANALYSES OF WELL WATERS FROM..**TIGNISH**..... MAP-AREA....**PRINCE**..... COUNTY

Sample number	Owner	Lot	Concession	Depth of well (feet)	Aquifer	Total dissolved solids (parts per million)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Alkalis (as Na and K)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Bicarbonate (HCO_3)	Alkalinity (as $CaCO_3$)	Ca hardness (as $CaCO_3$)	Mg hardness (as $CaCO_3$)	Total hardness (as $CaCO_3$)
							Constituents as Analysed (parts per million)										Hardness as parts ~~XXXX~~ per million		
1	W. Coughlin	4		30	Ss	106	6.2		11.2	9.0	8.0	5.8	9.0	6.2	65.9	58.0	27.9	37.0	64.9
2	W. Haywood	4		30	Ss	104	4.2		8.2	8.7	7.4	4.1	8.6	10.6	35.6	50.0	20.5	35.8	56.3
3	S. Corcoran	5		60	?	184	6.0		14.6	17.5	15.7	22.2	12.0	23.0	75.6	72.0	36.4	72.0	108.4
4	G. A. Palmer	Bloom.		30	Ss	246	17.0		46.7	16.6	8.8	3.3	10.3	tr.	215.5	176.6	116.5	68.3	184.8
5	L. Thomson	4		82	Ss	208	12.0		36.3	12.7	20.1	6.6	19.6	0.0	160.3	141.0	90.6	52.3	142.9
6	J. E. MacGregor	7		9	S	284	8.4		43.2	9.6	22.9	7.8	43.6	42.5	77.8	73.8	107.8	39.5	147.3
7	H. A. Thomson	7		38	Ss	360	12.6		48.0	22.5	34.9	11.5	32.7	76.4	168.4	138.0	120.0	92.3	212.3
8	R. Ashley	5		27	Ss	110	6.2		13.6	12.7	7.3	7.4	9.5	10.6	64.9	62.0	34.0	52.1	86.1
9	P. W. Pate	5		23	Ss	94	5.6		9.9	11.1	6.7	5.0	7.2	5.3	43.9	56.0	24.8	45.5	70.3
10	H. Ashley	5		15	Ss	110	7.8		13.5	13.1	9.2	5.8	10.6	4.4	75.6	74.0	33.8	53.7	87.5
11	R. H. Hunter	5		30	Ss	112	9.0		18.1	12.9	7.9	4.9	7.6	1.8	90.8	82.4	45.3	52.9	97.2
12	F. Luttrell	5		30	Ss	86	7.4		12.7	10.7	6.8	8.2	7.6	4.4	71.5	58.6	41.8	43.9	85.7

Sp - Spring Ss - Sandstone S - Sand

Bloom. - Bloomfield

867

ANALYSES OF WELL WATERS FROM...TIGNISH..... MAP-AREA.....PRINCE..... COUNTY

							Constituents as Analysed (parts per million)										Hardness as $CaCO_3$ (parts per million)		
Sample number	Owner	Lot	Concession	Depth of well (Feet)	Aquifer	Total dissolved solids (parts per million)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Alkalis (as Na and K)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Bicarbonate (HCO_3)	Alkalinity (as $CaCO_3$)	Ca hardness (as $CaCO_3$)	Mg hardness (as $CaCO_3$)	Total hardness (as $CaCO_3$)
13	A. Rix	4		42	?	138	4.6		17.0	7.3	6.4	26.3	11.5	1.6	78.1	64.0	42.4	30.0	72.4
14	I. Bernard	2		60	Ss	344	9.5		64.5	7.0	11.3	13.2	30.5	2.6	165.9	136.0	160.9	28.8	189.7
15	A. L. Rennie	Elmsdale		25	Ss	180	5.2		22.0	10.0	7.0	8.2	13.0	3.5	90.3	74.0	54.9	41.2	96.1
16	W. A. Feakes	3		21	Ss	246	5.1		33.0	7.5	22.8	6.2	25.0	10.6	114.7	94.0	82.3	30.9	113.2
17	E. Barbour	3		50	Ss	326	4.2		52.0	2.1	9.3	15.2	15.0	12.3	148.8	122.0	129.7	8.6	138.3
18	G. Jeffrey	3		100	?	176	5.2		39.0	3.4	9.9	6.2	9.5	2.6	108.0	90.0	97.3	14.0	111.3
19	J. A. Costain	3		Sp	S	204	6.6		61.6	2.4	12.2	23.9	15.4	19.5	139.1	114.0	128.7	9.9	138.6
20	J. H. Doucette	2		18	Ss	194	11.0		41.7	2.2	18.3	21.0	28.0	4.4	118.1	96.8	104.0	9.1	113.1
21	J. Ryan	2		28	Ss	112	6.0		23.4	2.2	8.5	7.8	11.4	6.2	67.8	55.6	58.4	9.1	67.5
22	A. Martin	2		40	Ss	86	7.5		13.5	3.9	8.6	11.5	10.8	7.1	48.1	39.4	33.7	16.0	49.7
23	F. Martin	2		Sp	S	122	6.8		18.0	5.3	13.1	14.0	16.8	4.4	65.9	54.0	44.9	22.6	67.5
24	J. A. Doucette	1		50	Ss	120	5.3		31.5	2.0	7.4	10.3	12.0	4.4	90.3	74.0	78.6	8.2	86.8

Sp - Spring   Ss - Sandstone   S - Sand

867

ANALYSES OF WELL WATERS FROM...TIGNISH..... MAP-AREA...PRINCE...... COUNTY

							Constituents as Analysed (parts per million)										Hardness as $CaCO_3$ (parts per million)		
Sample Number	Owner	Lot	Concession	Depth of well (Feet)	Aquifer	Total dissolved solids (parts per million)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Alkalis (as Na and K)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Bicarbonate (HCO_3)	Alkalinity (as $CaCO_3$)	Ca hardness (as $CaCO_3$)	Mg hardness (as $CaCO_3$)	Total hardness (as $CaCO_3$)
25	B. Keefe	1		8	S	380	6.8		43.0	11.1	70.5	22.6	89.0	63.8	73.2	60.0	107.3	45.5	152.8
26	Community Well	1		100	Ss	432	14.6		85.0	13.8	28.8	7.0	73.0	4.4	251.3	206.0	212.1	56.8	268.9
27	E. Broderick	1		Sp.	S	162	7.6		41.7	4.2	11.4	7.4	19.5	5.3	136.6	112.0	104.0	17.3	121.3
28	A. Ga in	1		40	Ss	356	8.4		40.0	22.3	47.1	18.9	65.0	37.2	168.4	138.0	99.8	91.8	191.6
29	F. J. Peters	St. L.		35	Ss	184	7.0		51.3	1.3	8.5	9.9	15.0	12.4	136.6	112.0	128.0	5.3	133.3
30	G. Kinch	Alb. S.		31	Ss	146	6.8		20.0	7.9	13.5	10.3	17.5	7.1	87.8	72.0	49.9	32.5	82.4
31	J. Gallant	Mim.		57	Ss	438	7.6		10.0	1.3	169.9	58.4	42.0	0.0	330.0	272.0	25.0	5.3	30.3
32	Tignish S ore	Tig.		40	Ss	530	6.4		101.0	12.5	66.5	88.1	101.0	17.7	195.2	160.0	252.0	51.4	303.4
33	Thos. Leclair	Tig.		24	Ss	666	6.4		91.0	16.8	98.4	161.0	93.0	70.9	139.1	114.0	227.1	69.1	296.2
34	Tignish Co-op	Tig.S.		327	Ss	200	9.6		11.0	0.2	65.1	14.8	23.0	0.0	141.4	116.0	27.5	0.8	28.3
35	W. R. Oulton	Alb.		30	Ss	126	7.2		29.0	9.6	10.4	11.1	21.0	0.7	107.4	88.0	72.4	39.5	111.9
36	C. Weeks	Alb.		42	Ss	90	1.2		22.0	7.9	7.4	8.6	13.0	5.3	78.1	64.0	54.9	32.5	87.4

Sp - Spring Ss - Sandstone S - Sand
St. L. - St. Louis Alb. S. - Alberton South Mim. - Miminegash Tig. - Tignish
Tig. S. - Tignish Shore Alb. - Alberton

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AND
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GEOLOGICAL SURVEY OF CANADA
WATER SUPPLY PAPER No. 313

GROUND-WATER RESOURCES OF TOWNSHIPS 11 to 14, RANGES 18 to 21, WEST OF 4th MERIDIAN, MANITOBA

(RIVERS AREA)

By

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OTTAWA
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PART I

INTRODUCTION

The present report is an attempt to assemble the data on ground-water resources in a form that will be useful to well drillers, farmers, municipal authorities, and others interested in obtaining adequate water supplies.

Publication of Results

The essential information pertaining to ground-water conditions is being issued in reports that, in Manitoba, cover a square block of sixteen townships lying between the correction lines and beginning at the Saskatchewan boundary. The reports on the most southerly strip of the province include in addition the two townships lying north of the International Boundary. The secretary-treasurer of each municipality will be supplied with the information covering that municipality, and copies of the reports will also be available for study at offices of the Provincial and Federal Departments. Further assistance in interpreting the reports may be obtained by applying to the Chief Geologist, Geological Survey of Canada, Ottawa.

How to Use the Report

Anyone desiring information concerning ground-water in any particular locality will find the available data listed in the well records, and other pertinent information on the maps of the area. For those unfamiliar with these reports it is, perhaps, advisable that that part dealing with the area as a whole be read first, so as to be in a better position to understand the more particular descriptions of each township that follow. Also, the map accompanying the report should prove a useful source of reference when reading the text.

The map consists of two figures. Figure I shows bedrock and surface geology. The water-bearing properties of the bedrock change from formation to formation, and are referred to in subsequent pages. The type of glacial deposit at the surface may be determined from the map, and its possibilities as an aquifer are also discussed in this report.

Figure 2 shows the location and types of wells in the area, the land relief (topography), and the drainage pattern. Not every well is plotted on the map, but most of those giving pertinent information are shown, and probably include 90 per cent of the wells in the area. Where ground water is not readily available, or carries too much dissolved salts to be used, dugouts often form the only means of supply. The topography is shown by contours, or lines of equal elevation, spaced at vertical intervals of 50 feet.

The well records are compiled from data obtained by interviewing farmers, and in many cases their accuracy depends upon the farmer's memory. Wherever possible data were checked by plumb-line measurement to the nearest foot. The wells are tabulated by townships and sections, and the total depth of the well, depths to the water level at high and low stages, and, where possible, the depth at which the water-bearing horizon occurs, are all listed. The general character of the water is stated, and the use to which it can be put. Wells from which samples were taken for analysis are indicated on the well-record sheets. An idea of how much water a well can be expected to yield is suggested by the number of stock (cattle and horses only) that can be watered at it. One head is assumed to consume between 8 and 10 gallons of water a day. Unless followed by the word "only"

the figure for the number of stock watered is not necessarily the maximum yield of the well, but simply the greatest amount that the present user has required. The word "only" indicates that the figure given is the maximum yield of the well. To obtain the position of an aquifer at any given point, the elevation of the point should be determined from the contours on Figure 2 of the map. Elevations of adjacent wells may be found in the well records and the depth to the aquifer can usually be determined from them. By comparing elevations the depth of the aquifer below the unknown point may be estimated. This method is particularly applicable to bedrock wells, but may not be successful where information is too limited, or where the glacial drift is thick and of an irregular character. In such instances a person searching for water should refer to the text for information on the nature of the deposits in that area.

GLOSSARY OF TERMS USED

Alkaline. The term 'alkaline' or 'alkali' water has been applied rather loosely to waters having a peculiar and disagreeable taste, and commonly a laxative effect. The waters so described in the Prairie Provinces are those heavily charged with sulphates of magnesium and sodium (respectively Epsom salts and Glauber's salts) and are more correctly termed sulphate waters. Truly 'alkaline' waters owe that property to the presence of calcium carbonate and calcium bicarbonate. In this report an attempt to adhere to local terminology is made by referring to sulphate waters as 'alkali' in the well records, and the term 'alkaline' is avoided.

Alluvium. Deposits of clay, silt, sand, gravel, and other material in lake beds and in flood plains of modern streams. The term also includes the material in river terraces, which once formed part of the flood plain but are now above it.

Aquifer. A porous bed, lens, pocket, or deposit of material that transmits water in sufficient quantity to satisfy pumping wells and springs.

Bedrock. Bedrock, as here used, refers to partly or wholly consolidated deposits of gravel, sand, silt, clay, and marl that are older than the glacial drift.

Bentonite and bentonitic clays have the property of swelling when water is added to them. They occur as white beds as much as 2 feet thick, but usually much thinner, and are probably formed by the weathering of volcanic ash.

Buried pre-Glacial Stream Channel. A channel eroded into the surface of the bedrock by a stream before the advance of the continental ice-sheet, and subsequently either partly or wholly filled in by sands, gravels, and boulder clay deposited by the ice-sheet or later agencies.

Coal Seam. The same as a coal bed. It is a deposit of carbonaceous material formed from the remains of plants by partial decomposition and burial.

Contour. A line on a map joining points that have the same elevation above sea-level.

Continental Ice-sheet. The great ice-sheet that covered most of the surface of Canada many thousands of years ago.

Escarpment. A cliff or relatively steep slope separating level or gently slopping areas.

Flood Plain. A flat part of a river valley ordinarily above water, but submerged when the river is in flood. It is an area where silt and clay are being deposited.

Glacial Drift. A general term that includes all the loose, unconsolidated materials that were deposited by the ice-sheet, or by the waters associated with it. Clay containing boulders usually forms a large part of the glacial drift in an area, and is called glacial till or boulder clay, and is not to be confused with the more general term glacial drift, which occurs in the following several forms:

(1) Terminal Moraine or Moraine. A ridge or series of ridges formed by glacial drift that was laid down at the margin of a moving ice-sheet. The surface is characterized by irregular hills and undrained basins.

(2) Kame Moraine. Assorted deposits of sand and gravel laid down at or close to the ice margin. The topography is similar to that of a terminal moraine.

(3) Ground Moraine. Boulder clay (till) laid down at the base of an ice-sheet. The topography may vary from flat to gently rolling.

(4) Glacial Outwash. Sand and gravel plains or deltas formed by streams that issued from the continental ice-sheet.

(5) Glacial-lake Deposits. Sand, silt, and clay deposited in glacial lakes during the retreat of the ice-sheet.

Shoreline. A discontinuous escarpment, with intervening gravel beaches and bars, which indicates the former margin of a glacial lake.

Ground Water. The water in the zone of saturation below the water-table.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it was first encountered in the well, namely, at the level of the aquifer.

Impervious or impermeable. Beds such as fine clays or shale are considered to be impermeable when they do not permit the perceptible passage or movement of ground water.

Pervious or Permeable. Beds are pervious or permeable when they permit the perceptible passage or movement of ground water, as in the case of sands and gravels.

Pre-Glacial Land Surface. The surface of the land as it existed before the ice-sheet covered it with drift.

Recent Deposits. Deposits that have been laid down by the agencies of water and wind since the disappearance of the continental ice-sheet; for example, alluvium in stream valleys.

Sand Point or Driven Well. A sand point is a piece of perforated and screened pipe 2 or 3 feet long, which ends in a sharp point. It is fastened to lengths of ordinary pipe and forced down into surface deposits of a sandy or gravelly nature. The depth of such a well rarely exceeds 30 feet.

Unconsolidated Deposits. The mantle or covering of alluvium, pre-glacial soils, and glacial drift consisting of loose, uncemented material that overlies the bedrock.

Variegated. Beds so described show different colours in alternating beds or lenses.

Water-table. The upper limit of the part of the ground saturated with water. This may be near the surface or many feet below it. A water-table is said to be perched when a zone of saturated material is separated from the main water-table below by a zone or zones of unsaturated material.

Water-worked Till. Glacial till or boulder clay that has been subjected to water action, usually near the margins of glacial lakes, so that the fine clay has been washed out and a deposit that may be composed mainly of sand and gravel is left behind.

Wells. The term refers to any hole sunk in the ground by any means for the purpose of obtaining water. If no water is obtained they are referred to as dry holes. Wells yielding water are divided into four classes:

(1) Flowing Artesian Wells. Wells in which the water is under sufficient hydrostatic pressure to flow above the surface of the ground at the well.

(2) Non-flowing Artesian (Sub-artesian) Wells. Wells in which the water is under sufficient hydrostatic pressure to raise it above the level of the aquifer, but not above the level of the ground at the well.

(3) Non-artesian Wells. Wells in which the water does not rise above the water-table or the aquifer.

(4) Intermittent Non-artesian Wells. Wells that are generally dry for a part of each year.

GENERAL DISCUSSION OF GROUND WATER

Almost all the water recovered from beneath the earth's surface for both domestic and industrial uses is meteoric water, that is, water derived from the atmosphere. Most of this water reaches the surface as rain or snow. Part of it is carried off by streams as run-off; part evaporates either directly from the surface and from the upper mantle of soil, or indirectly through transpiration of plants; and the remainder sinks into the ground to be added to the ground-water supplies.

The proportion of the total precipitation that sinks into the ground will depend largely upon the type of soil or surface rock, and on the topography; more water will sink into sand and gravel, for example, than into clay; if, on the other hand, the region is hilly and dissected by numerous streams, more water will be immediately drained from the surface than in a relatively flat area. Light, continued precipitation will furnish more water to the underground supply than brief torrential floods, during which the run-off may be nearly equal to the precipitation. Moisture failing on frozen ground will not usually find its way below the surface, and, therefore, will not materially replenish the ground-water supplies. Light rains falling during the growing season may be wholly absorbed by plants. The quantity of moisture lost through direct evaporation depends largely upon temperature, wind, and humidity. Locally these deposits may become very extensive. The water-bearing properties of alluvial deposits are variable, but, in general, such deposits form favourable aquifers. They are porous, and readily yield a part of their contained water, although in places their porosity may be greatly reduced by the presence of fine silt and clay. This type of deposit may be expected to yield moderate domestic supplies through shallow wells, and larger supplies if the deposits are extensive.

In some areas of relatively steep slopes, valleys have been partly filled with sand and gravel, which, in turn, have been covered with impervious clay and silt. These circumstances commonly give rise to artesian conditions in the lower part of the valley.

DISCUSSION OF WATER ANALYSES

Both the kind and quantity of mineral matter dissolved in a natural water depend upon the texture and chemical composition of the rocks with which the water has been in contact. Pollution is caused by contact with organic matter or its decomposition products. Analyses of well waters for mineral content are made by the Department of Health and Public Welfare, Winnipeg, and by the Bureau of Mines, Department of Mines and Resources, Ottawa.

As the ground-water survey of Manitoba progresses an effort is made to secure samples representative of each major aquifer encountered; the purpose of this is to compare the chemical characteristics of waters from the various geological horizons and, thereby, assist in making correlations of the strata in which the waters occur. The mineral content of natural waters is also of interest to the consumers, though the effects of the constituents are usually already apparent. The quantities of the various constituents for which tests are made are given as 'parts per million', which refers to the proportion by weight of each constituent in 1,000,000 parts of water. A salt when dissolved in water separates into two chemical units called 'radicals', and these are expressed as such in the chemical analyses. In one group are included the metallic elements of calcium (Ca), magnesium (Mg), sodium (Na), and iron (Fe), and in the other group are the sulphate (SO_4), chloride (Cl), bicarbonate (HCO_3), carbonate (CO_3), and nitrate (NO_3) radicals. The radicals listed in the analyses tabulated in the second part of this report can be combined to give the actual quantity of the particular salts present in the water, but this is not done here as the radicals alone give enough information to identify the water types. In fact, the sulphate, chloride, and carbonate radicals, plus the hardness, serve to identify a water, and crude field tests on the basis of these constituents were used in some areas to outline more completely zones of the various water types.

The following mineral constituents include all that are commonly found in natural waters in quantities sufficient to have any practical effect on the value of waters for ordinary uses:

Silica (SiO_2) is dissolved in small quantities from almost all rocks. It is not objectionable except in so far as it contributes to the formation of boiler scale.

Iron (Fe) in combination is dissolved from many rocks as well as from iron sulphide deposits with which the water comes in contact. It may also be dissolved from well casings, water pipes, and other fixtures in quantities large enough to be objectionable, but separates as the hydrated oxide upon exposure of the water to the atmosphere. Excessive iron in water causes straining on porcelain or enamelled ware, and renders the water unsuitable for laundry purposes. Water is usually considered not potable if the iron content is more than 0.5 part per million.

Calcium (Ca) in the water comes from mineral particles present in the surface deposits, the chief sources being limestone, gypsum, and dolomite. Fossil shells provide a source of calcium, as does also the decomposition of igneous rocks. The common compounds of calcium are calcium carbonate ($CaCO_3$) and calcium sulphate ($CaSO_4$), neither of which have injurious effects on the consumer, but both of which cause hardness.

Magnesium(Mg) is a common constituent of many igneous rocks and, therefore, very prevalent in ground water. Dolomite, a carbonate of calcium and magnesium, is also a source of the element. The sulphate of

magnesia ($MgSO_4$) combines with water to form 'Epsom salts,' and renders the water unwholesome if present in large amounts.

Sodium(Na) is derived from a number of the important rock-forming minerals, so that sodium sulphate and carbonate are very common in ground waters. Sodium sulphate (Na_2SO_4) combines with water to form 'Glauber's salt' and excessive amounts make the water unsuitable for drinking purposes. Sodium carbonate (Na_2CO_3) or 'black alkali' waters are mostly soft, the degree of softness depending upon the ratio of sodium carbonate to the calcium and magnesium salts. Waters containing sodium carbonate in excess of 200 parts per million are unsuitable for irrigation purposes[1]. Sodium sulphate is less harmful.

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[1]"The extreme limit of salts for irrigation is taken to be 70 parts per 100,000, but plants will not tolerate more than 10 to 20 parts per 100,000 of black alkali (alkaline carbonates and bicarbonates)". Frank Dixey, in 'A Practical Handbook of Water Supply', Thos. Murby & Co., 1931, p. 254.

Sulphates (SO_4) referred to in this report are those of calcium, magnesium, and sodium, and have been mentioned above in referring to those radicals. They are also formed by oxidation of iron sulphides, and, hence, it is not uncommon to find iron in sulphate waters. Sulphates cause permanent hardness in water, and injurious boiler scale. Sodium and magnesium sulphates are laxative when present in quantities of more than 900 parts per million. The writers found that acclimatized people could drink water containing as much as 2,000 parts per million of all three of the principal sulphates, but that when all were present in quantities over 1,500 parts per million the water was commonly laxative to those not accustomed to it.

Chloride (Cl) is a constituent of all natural waters and is dissolved in small quantities from rocks. Waters from wells that penetrate brines or salt deposits contain large quantities of chloride, usually as sodium chloride (common salt) and less commonly as calcium chloride and magnesium chloride. Sodium chloride is a characteristic constituent of sewage, and any locally abnormal quantity suggests pollution from this source. However, such abnormal quantities should not, in themselves, be taken as positive proof of pollution in view of the many sources from which chloride may be derived. Chlorides impart a salty taste to water if present much in excess of 500 parts per million. In southwestern Manitoba waters with as much as 3,000 parts per million of chloride are used domestically, though more than 1,500 parts per million is generally considered undesirable. The following figures apply to chlorides: stock will require less salt if the water bears 2,000 parts per million; more than 5,000 parts per million is unfit for human consumption; more than 8,000 parts per million is unfit for horses; more than 9,500 parts per million is too much for cattle; and more than 15,500 parts per million is excessive for sheep. Magnesium chloride, less common than sodium chloride, is very corrosive to metal plumbing.

Nitrates(NO_3) found in ground water are decomposition products of organic materials; they are not harmful in themselves, but they do point to probable pollution. It is recommended that a bacterial test be made on water showing an appreciable nitrate content, if it is to be used for domestic purposes.

Carbonates (CO_3) in water are indicated in the table of analyses as 'alkalinity'. Calcium and magnesium carbonate cause hardness in water, which may be partly removed by boiling. Sodium carbonate causes softness in waters, and is referred to under 'Sodium' above.

Bicarbonates (HCO_3). Carbon dioxide dissolved in water renders the insoluble calcium and magnesium carbonates soluble as bicarbonates. The latter are decomposed by boiling the water, which changes them to insoluble carbonates.

Hardness is a condition imparted to waters chiefly by dissolved calcium and magnesium compounds. It here refers to the soap-destroying power of water, that is, to the amount of soap that must first be used to precipitate the above compounds before a lather is produced. The hardness of water in its original state is its total hardness, and is classified as 'permanent hardness' and 'temporary hardness'. Permanent hardness remains after the water has been boiled. It is caused by mineral salts that cannot be removed from solution by boiling, but it can be reduced by treating the water with natural softeners, such as ammonia or sodium carbonate, or with many manufactured softeners. Temporary hardness can be eliminated by boiling, and is due to the presence of bicarbonates of calcium and magnesium. Waters containing large quantities of sodium carbonate and small amounts of calcium and magnesium compounds are soft, but if the latter compounds are present in large quantities the water is hard. The following table[1] may be used to indicate the degree of hardness of a water:

[1]Thresh, J.C., and Beale, J.F.: The Examination of Waters and Water Supplies; London, 1925, p. 21.

Total Hardness

Parts per million	Character
0-50	Very soft
50-100	Moderately soft
100-150	Slightly hard
150-200	Moderately hard
200-300	Hard
300 +	Very hard

The above table gives the generally accepted figures for hardness, but the people of southwestern Manitoba have become accustomed to harder waters, and the following table, based on about 800 field determinations of hardness, by the soap method, is more applicable:

Parts per million	Character
0-100	Very soft
100-150	Soft
150-250	Moderately hard
250-350	Hard
350-500	Very hard
500+	Excessively hard

Waters having a hardness of up to 300 parts per million are commonly used for laundry purposes. In southwestern Manitoba, hardness ranges from less than 50 parts per million to more than 2,500 parts per million.

PART II

TOWNSHIPS 11 TO 14, RANGES 18 TO 21, WEST PRINCIPAL MERIDIAN, MANITOBA

(Rivers area)

Introduction

An investigation of the glacial geology and the ground water resources of tps. 11 to 14, rges. 18 to 21, W. Princ. mer., was conducted by the writer during the field season of 1950.

Physical Features

The general character of the topography is that of an uneven, rolling plain with undrained depressions and wooded areas of scrub aspen and poplar. The southern part is flatter, as the surface was modified by the waters of glacial Lake Souris. Minnedosa River crosses the area in a valley narrow north of Rapid City and wider with gently sloping sides south of it. The river flows southwest to a point south of Rivers where it turns southeast and joins the Assiniboine in tp. 10, rge. 20, south of the area.

The altitudes vary from more than 1,900 feet above sea-level in the northern part of the area to less than 1,250 feet above sea-level in the floor of the valley in which Assiniboine River crosses the southwest corner.

Geology

Table of Formations

Age	Formation	Character	Thickness (feet)
Recent	Alluvium	Stream-laid mud, silt, sand, and gravel	
Pleistocene	Lake beds	Silty clay, fine sand and silt, duned sand, assorted sand, and gravel, in beaches and deltas	0-50
	Glacial drift	Till, clay, sand, gravel, boulders, assorted sand, and gravel, in outwash plains	0-400
Upper Cretaceous	Riding Mountain	Upper beds of medium to light grey, hard, siliceous shale (Odanah shale), with some thin layers of fine, blue sand and bentonite beds; lower beds of slippery clay shale that tends to slump	1,000 +
	Vermilion River	Dark grey and black shale, comprising three members: Pembina (dark shale, numerous bentonite bands near base); Boyne (grey, calcareous shale, non-calcareous dark shale near base); and Morden (calcareous speckled shale, over-lying dark grey, non-calcareous, blocky shale with thin partings of white sand)	80 ± 140 ± 190 ±

Age	Formation	Character	Thickness (feet)
	Favel	Grey shale with white calcareous material; some bands of limestone; some bentonite	150 ±
Lower and Upper Cretaceous	Ashville	Dark grey to black shale with silt and sand	40 ±
Lower Cretaceous	Swan River	White to green sandstone, black shale, and silt	50 +
Jurassic		Light grey to red shale, calcareous sandstone, grey to buff to brown shale, light grey limestone and sandstone	380 ±
Jurassic or earlier	Amaranth	Red beds and gypsum	220

Upper Cretaceous shales of the Riding Mountain formation underlie the overburden in this area, but their water-bearing possibilities have not been investigated as only one well pumps water from bedrock.

The overburden over much of this area consist of ground moraine, in places modified by the action of water. The upper 20 feet or more is made up of a buff weathered till in which local and temporary flows of meltwater have brought about enough sorting to produce the pockets or lenses of sand and gravel now encased in the till. These lenses form local aquifers that commonly yield a sufficient supply of water for household use. Underlying the weathered till is a blue, clay-rich till that is, in places, more than 300 feet thick. This till is impervious and test holes drilled into it are dry.

Meltwater from ice masses that stagnated at Riding and Duck Mountains followed the present courses of Oak and Minnedosa Rivers. Upon reaching glacial Lake Souris the waters of these streams dumped their load of sand and gravel, building an outwash plain with its apex at Rivers that extended south to the Assiniboine Valley. At Rivers and Wheatland the sand and gravel averages 20 feet in thickness.

Water Supply

One well reaches bedrock and yields an abundant supply of water that is hard and precipitates iron. Other wells drilled to bedrock could be expected to supply abundant water, but the thickness of overburden that has to be penetrated makes the drilling of such a well costly.

Good water, sufficient for a household or farm supply, is being obtained in the area of outwash sand and gravel in and south of Rivers.

Local patches and lenses of sand and gravel are the only source of water in the glacial deposits, and where these are lacking dugouts are needed. In tps. 13 and 14, rge. 20, for instance, test holes have been dug into impervious clay to depths of 300 feet. The supply of water in this area is not sufficient and is lacking in many sections. The supply for stock can, however, be assured by building dugouts.

Artesian aquifers are known in an area near Forrest. In section 1, tp. 12, rge. 19, and in sections 23 and 24, tp. 11, rge. 19, wells encountered water that flowed at the surface from a zone of coarse sand below blue clay at depths of 72, 36, and 47 feet respectively. Other flowing wells are recorded in sections 7 and 26, tp. 14, rge. 20.

Township 11, Range 18. The surface of this township is uneven to flat, sloping south to the Assiniboine Valley. Waters of glacial Lake Souris modified the surface material, and silt and clay deposited on the lake bottom filled undrained depressions smoothing the surface. A branching intermittent creek follows broad shallow channels across the township.

Ground water is recovered from glacial drift, and neither the depth to bedrock nor its water-bearing possibilities are known from well records. The upper 20 feet of the glacial drift is buff weathered till and below this is a clay-rich blue till of variable thickness. The wells are bored 30 to 95 feet through the blue till to aquifers of fine sand and gravel. The supply of water is commonly sufficient, but wells are on record that will supply only 12 to 15 head, and others that are dry in winter months.

In NE.$\frac{1}{4}$ section 23 a bored well 60 feet deep reached an aquifer below blue clay. When the well was completed the water was under sufficient pressure to rise to the surface and flow, but at present it rises to a point 9 feet from the surface.

The quality of the water is characteristic of that from southwestern Manitoba, that is, it has a concentration of sulphate salts and hence is known locally as alkali water. The iron content is high enough in some water to make it unsuitable for household use.

Township 11, Range 19. The uneven surface of this township slopes south to the Assiniboine Valley. Ground moraine modified by waters of glacial Lake Souris covers the township except in the southwest quarter where sandy deposits formed in the lake cover an area of twelve or more

sections. Wells 10 to 16 feet deep, dug into this sand, supply an abundance of good water in sections 4, 5, 8, 17, and 18. Elsewhere wells are dug or bored 40 to 100 feet to aquifers below blue clay.

The water in this township is hard with much iron, but commonly sufficient for 20 or more head of stock. In NW.$\frac{1}{4}$ sections 23 and 24, wells bored 36 and 37 feet respectively reach an aquifer below blue clay, and in both wells the water is under sufficient pressure to rise to the surface and flow. Test holes 100 to 128 feet deep dug on sections 14 and 20 were dry, and dugouts are the only source of supply. A well 26 feet deep in NE.$\frac{1}{4}$ of section 6 was never sufficient and commonly dry until the last 2 years and now will water 60 head of stock.

The water-bearing possibilities of the bedrock are not known, as no wells are recorded that reach it. Wells drilled 125 feet penetrate blue clay for this entire distance.

Township 11, Range 20. The rolling surface of this township has been smoothed by waters of glacial Lake Souris. In the southern part of the township sandy lake-beds are common, but elsewhere ground moraine covers the township except where outwash gravel is present along Minnedosa River Valley.

Wells that average 10 feet in depth in sections 1 to 6, inclusive, supply an abundance of water. Similar wells in outwash gravel are found in sections 9, 10, 15, and 16.

In the northern part of the township wells are bored to depths of 90 to 100 feet to aquifers below blue clay, and with some exceptions yield an abundant supply of water that is commonly alkali and iron-bearing. The supply of water in this part has been a problem to maintain because the fine sand below the blue clay becomes quicksand when penetrated and rises in the lower part of the casing, thus sealing off the source of water.

A dry hole in SW.$\frac{1}{4}$ section 18 was drilled 345 feet deep, but on the same quarter section a hole drilled 215 feet reached an aquifer at 140

feet and the water rose to a point 70 feet below the surface of the well. Dry holes drilled in sections 10 and 14 reached bedrock at depths of 100 to 140 feet respectively.

Township 11, Range 21. In the area of outwash gravel that covers the northwest quarter of the township and extends to Assiniboine River, water can be obtained at moderate depths. Elsewhere water may be obtained from sand or gravel layers below blue clay at depths of from 70 to 90 feet, although this is not certain and some dry holes have been dug or drilled. Test holes in sections 1, 7, and 14 reached depths of 225, 147, and 103 feet respectively, and each penetrated sand and gravel that was dry.

Springs along the Minnedosa Valley are a source of supply in sections 27 and 34. The supply of water is also plentiful in most wells, particularly along the Assiniboine Valley where one well in SW¼ section 17, 55 feet deep, yields 250 gallons a minute, the water being pumped through a pipe line to the Rivers Airport.

Township 12, Range 18. Ground moraine covers the township and two intermittent creeks flow south across it. The surface slopes from an elevation of 1,650 feet above sea-level in the northwest corner of the township to less than 1,450 feet in the southeast corner.

Shallow dug wells in gravel along the creeks yield an abundance of good water. Elsewhere wells are dug or drilled 40 to 100 feet to gravel or sand below blue clay. In sections 33, 31, and 27 drilled wells reach layers of sand or gravel at depths of 100 and 140 feet and water of average quality rises 50 to 70 feet in the casing. The water is hard, commonly alkali, with much iron. On SW.¼ section 32, a dugout is the only source of supply, as test holes 130 and 152 feet deep penetrated blue clay and were dry.

Township 12, Range 19. Ground moraine, which covers the township, has an uneven surface with undrained depressions and clumps of scrub poplar and aspen.

The water supply is not abundant and dugouts are needed to assure sufficient water for stock. In sections 11, 19, 34, and 35 shallow dug wells 10 to 20 feet deep yield water from local surface deposits of sand in ground moraine, and elsewhere water is obtained at depths of 80 to 140 feet in wells bored or drilled to a layer of fine sand below blue clay. However, dry holes 140, 100, 300, and 150 feet have been drilled in sections 16, 22, 25, and 31.

The water from the bedrock is hard and alkali and only one well, in SE.$\frac{1}{4}$ section 17, at a depth of 288 feet, has been drilled into it.

Along highway No. 10, in the southeast corner of SE.$\frac{1}{4}$ section 1, a test hole drilled by California Standard Company encountered a strong flow of fresh water at a depth of 72 feet in a zone of coarse sand. The water was alkali and the flow approximated 93 gallons a minute. Fifty-six feet of casing was run in the hole and cemented to control the water flow and plug the hole.

<u>Township 12, Range 20</u>. This township is covered with ground moraine with an uneven surface marked by undrained depressions and wooded areas. Across its northeast corner Minnedosa River occupies a broad valley with gently sloping sides.

In most of the township, water may be obtained from layers of gravel or sand underlying blue clay. In general these may be reached by wells 50 to 80 feet deep, but in sections 1, 2, and 3, wells 120 to 130 feet deep are necessary. In sections 13, 24, and 26 local lenses of outwash gravel yield water at depths of 10 to 18 feet. Dugouts are seldom used, but in SE.$\frac{1}{4}$ section 14, where test holes were dry, they are the only source of supply.

<u>Township 12, Range 21</u>. Minnedosa River crosses the southeast quarter of the township in a broad valley with gently sloping sides. An outwash plain built by an earlier river that followed the course of the present Minnedosa covers that part of the township west of the river.

Water can be obtained everywhere from outwash gravels at depths of less than 20 feet except at Rivers, where most wells are 20 feet or more deep. In those areas where the outwash gravels are not present, especially in sections 29 to 36, a supply of water that is not sufficient and is of poor quality is obtained from lenses of sand in blue clay at depths not greater than 40 feet.

The following test holes were drilled by The International Water Supply Limited, Regina, Saskatchewan, in search of water for the Airport.

No.	$\frac{1}{4}$ Section	Elevation (Feet)	Depth (Feet)	Aquifer (Feet)	Pumping test
	NE.8	1,550	189	0-75 sand	Insufficient water
	NE.8	1,550	249	92-98 fine sand	5 imperial gallons a minute(IGPM)
1	NW.16	1,500	79		No water
2	NW.16	1,500	65	50-52 fine sand	Insufficient water
3	NW.16	1,500	62	52-59 gravel	10 IGPM., drawdown $1\frac{1}{2}$ feet
4	NW.16	1,502	61	51-59 gravel	10 IGPM., drawdown nil
5	NW.16	1,550	70		No water
6	NE.16	1,502	63	53-63 sand	8 IGPM.
7	SW.16	1,554	75		No water
8	NW.16	1,550	67	60-63 sand	2 IGPM
9	NW.16	1,550	54	53-54 sand	No water
10	NW.16	1,550	66	53-65 gravel	10 IGPM
11	NW.16	1,550	63	53-61 gravel	20 IGPM., drawdown nil
12	SW.16	1,554	89		No water
13	NE.17	1,502	229		No water

No.	$\frac{1}{4}$ Section	Elevation (Feet)	Depth (Feet)	Aquifer (Feet)	Pumping test
14	SW.16	1,554	89	69-74 fine sand	No water
15	NW.16	1,500	67	60-64 fine sand	Little water
16	NE.17	1,502	72		No water
17	NE.17	1,502	68	58-68 sand	Little water

Township 13, Range 18. The water supply has presented a problem in this township, and until dugouts were built water in sufficient quantity was not available for stock. Twelve sections are dependent on dugouts for stock supply and household use, but drinking water must be hauled from nearby towns. The few wells present are dug into local pockets of surface sand in the ground moraine or to the base of the buff weathered till that averages 20 feet in thickness. The buff weathered till is underlain by impervious blue clay and aquifers that occur below this clay in other townships are not present here.

In NE.$\frac{1}{4}$ section 22 a test hole penetrated 300 feet of blue clay and four test holes in section 15 penetrated blue clay to depths of 103, 151, 164, and 190 feet and none encountered water. In SW.$\frac{1}{4}$ section 14 a spring issuing from the surface gravel yields a supply of water sufficient for 100 head in dry years.

Township 13, Range 19. Minnedosa River crosses the northeast quarter of the township in a valley that is narrow as far as Rapid City and wider south from there. Gravel, deposited as outwash, underlies Rapid City and mantles the east side of the valley.

A good supply of water is available in the town, the creamery, for example, obtaining sufficient water from two dug wells 15 and 20 feet deep into gravel. The remainder of the township depends on shallow wells dug into local surface deposits of gravel or in ground moraine at the

contact of the weathered upper till and the underlying blue clay. The supply is not abundant and where water cannot be obtained under the above conditions it is useless to dig or drill deeper into the impervious blue clay. Nine sections in which this is true are dependent entirely on dugouts.

Township 13, Range 20. Minnedosa River follows a broad valley with gently sloping sides that crosses the southeast quarter of the township. Except in the valley the entire township is covered by ground moraine.

Shallow wells in local pockets of fine sand or gravel yield a supply sufficient for domestic needs. Deeper wells bored or drilled into blue clay are not satisfactory and commonly the water of such clay is exhausted within 6 months of the time the well is dug.

In SW.$\frac{1}{4}$ Section 19, however, after three test holes 40, 57, and 75 feet deep proved dry, an additional test hole was drilled to a depth of 360 feet, encountering shale at 358 feet. This well obtained an abundant supply of water. The water from this well is hard with a concentration of sulphates and much iron, but it is better quality than water from the till. It is evident that adequate supplies of water cannot be obtained in much of this township unless the costly method of drilling to bedrock is attempted. Dugouts will in most places be required to assure a sufficient supply for stock.

Township 13, Range 21. In the southern part of this township a limited supply of water is obtained from shallow wells less than 20 feet deep dug into the weathered buff till or into pockets of sand, but dugouts are needed to assure a stock supply. Dry holes 150 and 300 feet deep were drilled on sections 3, 4, and 13. A drilled well 147 feet deep in SE.$\frac{1}{4}$ section 20 and 138 feet deep in section 21 yield a sufficient supply of hard, alkali water with much iron.

In the northern part of the township many wells dug 50 to 100 feet deep into lenses of gravel and sand within the till commonly yield sufficient water. In section 2, however, holes drilled 95, 135, and 275 feet in depth were dry.

Township 14, Range 18. Ground moraine covers this township and test holes indicate 345 feet of clay overlying bedrock in section 12. In sections 18 and 19, however, a bed of sand less than 10 feet thick covers the ground moraine and wells dug in this obtain an adequate supply of water. In some sections wells dug to lenses of sand or gravel in the upper 20 to 30 feet of weathered till obtain water, but 18 sections are dependent on dugouts for a supply. The search for water has been costly and not too successful. Test holes 110 to 375 feet deep have been drilled on sections 2, 5, 10, 12, 15, 21, and 24, all of which were in blue clay and dry. In NE.$\frac{1}{4}$ section 5, however, a well 86 feet deep reaches an aquifer at 85 feet from which fresh water rises 72 feet in the casing. Another well in SE.$\frac{1}{4}$ section 22 obtained water that rises to within 22 feet of the surface from a layer of sand at a depth of 70 feet.

Township 14, Range 19. Minnedosa River flows along the east side of the township in a valley with steep walls 150 feet high. East of the river the wells are less than 25 feet deep and obtain supplies from lenses of sand in the upper weathered part of the ground moraine.

West of the river, however, the supply of water is a problem, and 17 sections depend on dugouts, although in sections 3, 8, and 9 dug wells yield water from local pockets of gravel in ground moraine. In NW.$\frac{1}{4}$ sections 31 and 33 wells drilled 105 and 200 feet, respectively, to aquifers in blue clay yield abundant hard water with much iron.

Township 14, Range 20. This township is underlain by ground moraine whose surface is uneven, much wooded, and covered with undrained depressions.

Near Moline, wells dug or bored 60 to 80 feet obtain an excellent supply of water from a layer of gravel below blue clay. The water is hard, has much iron, and rises to a point within 20 feet of the surface of the

ground. Elsewhere, wells are dug 30 to 40 feet to lenses of sand or gravel in the ground moraine except in sections 26, 28, and 29, where wells are drilled 110, 200, and 150 feet respectively.

Township 14, Range 21. Ground moraine with an uneven, wooded surface covers the township. This ground moraine has local pockets of sand distributed all through it, which supply water to wells dug 30 to 50 feet deep. This water is hard, commonly alkali, and contains much iron. In NE.$\frac{1}{4}$ section 30, SW.$\frac{1}{4}$ section 31, and SW.$\frac{1}{4}$ section 32 wells are drilled 135, 155, and 165 feet, respectively, to bedrock.

At Cardale, two wells about 50 feet apart are dug to gravel below blue clay at depths of 30 and 36 feet. These wells yield an abundant supply of hard water that is slightly alkali and contains much iron.

ANALYSES OF WELL WATERS FROM Tps. 11 to 14, Rges. 18 to 21, W. Princ. mer. Man (Rivers Area)

										Constituents as Analysed (parts per million)								Hardness as($CaCO_3$) (pts. per million)		
Sample Number	¼	Section	Township	Range	Meridian	Owner	Depth of well (feet)	Aquifer *	Total dissolved solids (parts per million)	Calcium (Ca)	Magnesium (Mg)	Alkalis (as Na)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Bicarbonate (HCO_3)	Alkalinity (as $CaCO_3$)	Ca hardness	Mg hardness	Total hardness
4751	S.W.	19	13	20	WPM	G. Shanks	360	Sh.	2060	204.0	45.0	393.1	1126.5	154.0	4.4	122.0	100.0	509.0	185.2	694.2
4752	S.W.	34	13	18	WPM	J. Calen	12	Gr.	2162	308.0	151.0	80.0	809.9	199.0	354.0	246.4	202.0	768.5	621.4	1389.9
4753	S.W.	36	11	19	WPM	H. Heide	54		1398	405.0	115.4	270.0	1291.0	229.0	0.0	507.5	416.0	1010.5	474.9	1485.4
4754	S.W.	28	11	19	WPM	R. J. Marvin	50	Sd.	2842	554.0	144.7	39.8	1611.6	0.0	7.1	461.2	378.0	1382.2	595.4	1977.6

* Symbols used for aquifers

Discussion of Analyses

Four samples of water from the Rivers area were selected for analyses, the results of which are in the foregoing table. The numbers in the first column are for laboratory identifications and have no significance.

Sample No. 4751. The water is hard and the sulphate concentration is high. Water with a high sulphate concentration commonly precipitates a red mass of iron hydroxide that makes the water unsuitable for laundry purposes. This sample is from bedrock and is better water than the other samples analysed.

Sample No. 4752. This water is taken from a dug well in a local pocket of sand. In percolating through the porous surface deposits the water has picked up and concentrated the constituents shown in the analyses and is very hard.

Sample Nos. 4753 and 4754 appear to be from similar wells about 3 miles apart, but the quality of the water differs greatly. This is a good example of the variation in the quality of the water within short distances because of the heterogeneous nature of the glacial material, and possibly also because of the concentration of soluble minerals in lenses in the till.

Record of Wells

The well records of the Rivers area follow in tabulated form. A commentary on these has been made on page 1 of this report.

As a rule, the depth to the 'Principal Water-bearing Bed', has been taken as the total depth of the well, and its elevation given as such. This commonly applies to wells drilled into bedrock or to wells obtaining water from the sub-artesian or artesian aquifer in glacial or bedrock formations; digging or drilling is continued until a good supply

is obtained and then operations are stopped. In shallow surface deposits (to a depth of 30 feet), wells are usually dug a little lower than the water-table during a dry season, and thereafter water may enter and leave the well at a point below the normal water-table. The height to which water will rise in the well depends on the amount of rainfall for the season and on the lowering of the water-table by excessive pumping. During the field season of 1950 the amount of rainfall was above average and the recorded height to which water will rise is higher than average.

Wells that are dug beside dugouts are not included in the well records.

CANADA

DEPARTMENT OF MINES

AND

TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

WATER SUPPLY PAPER No. 314

GROUND-WATER RESOURCES OF TOWNSHIPS 31 to 34, RANGES 25 to 29, WEST OF 4th MERIDIAN ALBERTA

(Wimborne Area)

By

A. Mac S. Stalker

OTTAWA

1953

NOTE:

Because of difficulties involved in reproduction, the tables of well records referred to are not included with this report. Information regarding individual wells may be obtained by writing to the Director, Geological Survey of Canada, Ottawa.

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CONTENTS

Illustrations

INTRODUCTION

The survey of the ground-water resources of the Red Deer region, Alberta, was resumed during the field season of 1946, and much information on these resources was obtained by a compilation of records of water wells.

A division has been made in the well records, in so far as possible, between the glacial and bedrock water-bearing sands. The water records themselves were obtained mostly from the well owners, some of whom had acquired the land after the water supply had been found, and hence had no personal knowledge of the water-bearing beds that had been encountered in their wells. Also, the elevations of the wells were taken by aneroid barometer and are, consequently, only approximate. In spite of these defects, however, it is hoped that the publication of these water records may prove of value to the farmers, town authorities, and drillers in their efforts to obtain adequate water supplies.

Publication of Results

The essential information pertaining to ground-water conditions is being issued in reports that in Saskatchewan cover each municipality, and in Alberta cover each square block of sixteen townships beginning at the 4th meridian and lying between the correction lines. The secretary-treasurer of each municipality in Saskatchewan and Alberta will be supplied with the information covering that municipality. Copies of the reports will also be available for study at offices of the Provincial and Federal Departments. Further assistance in the interpretation of the reports may be obtained by applying to the Chief Geologist, Geological Survey, Ottawa. Technical terms used in the report are defined in the glossary.

How to Use the Report

Anyone desiring information concerning ground water in any particular locality will find the available data listed in the well records. These should be consulted to see if a supply of water is likely to be found in shallow wells sunk in the glacial drift, or whether a better supply may be obtained at greater depth in the underlying bedrock formations. The wells in glacial drift commonly show no regional level, as the sands or gravels in which the water occurs are irregularly distributed and of limited extent. As the surface of the ground is uneven, the best means of comparing water wells is by the elevations of their water-bearing beds. For any particular well this elevation is obtained by subtracting the figure for the depth of the well to the water-bearing bed from that for the surface elevation at the well. For convenience, both the elevation of the wells and the elevation of the water-bearing bed or beds in each well are given in the well-record tables. Where water is obtained from bedrock, the name of the formation in which the water-bearing sand occurs is also listed in these tables, and this information should be used in conjunction with that on bedrock formations, provided in the report, which describes these formations and gives their thickness and sequence. Where the level of the water-bearing sand is known, its depth at any point can easily be calculated by subtracting its elevation, as given in the well-records tables, from the elevation of the surface at that point.

With each report is a map consisting of two figures. Figure 1 shows the distribution and type of surface deposits and bedrock formation that occur in the area. Figure 2 shows the locations of all wells for which records are available, the class of well at each location, and the contour lines or lines of equal elevation. The elevation at any location can thus be roughly judged from the nearest contour line, and the records of the wells show at what levels water is apt to be encountered. The depth of the well can then be calculated, and some information on the character and quantity of water can be obtained from a study of the records of surrounding wells.

GLOSSARY OF TERMS USED

Alkaline. The term "alkaline" has been applied rather loosely to some ground waters that have a peculiar and disagreeable taste. In the Prairie Provinces, water that is commonly described as alkaline usually contains a large amount of sodium sulphate and magnesium sulphate, the principal constituents of Glauber's salt and Epsom salts respectively. Most of the so-called alkaline waters are more correctly termed sulphate waters, many of which may be used for stock without ill effect. Water that tastes strongly of common salt is described as salty.

Alluvium. Deposits of earth, clay, silt, sand, gravel, and other material on the flood-plains of modern streams and in lake beds.

Aquifer. A porous bed, lens, or pocket in unconsolidated deposits or in bedrock that carries water.

Buried pre-Glacial Stream Channel. A channel carved into bedrock by a stream before the advance of the continental ice-sheet, and subsequently either partly or wholly filled in by sands, gravels, and boulder clay deposited by the ice-sheet or later agencies.

Bedrock. Bedrock, as here used, refers to partly or wholly consolidated deposits of gravel, sand, silt, clay, and marl that are older than the glacial drift.

Coal Seam. The same as a coal bed. A deposit of carbonaceous material formed from the remains of plants by partial decomposition and burial.

Contour. A line on a map joining points that have the same elevation above sea-level.

Continental Ice-sheet. The great ice-sheet that covered most of the surface of Canada many thousands of years ago.

Escarpment. A cliff or a relatively steep slope separating level or gently sloping areas.

Flood-plain. A flat part in a river valley ordinarily above water but covered by water when the river is in flood.

Glacial Drift. The loose, unconsolidated surface deposits of sand, gravel, and clay, or a mixture of these, that

were deposited by the continental ice-sheet. Clay containing boulders forms part of the drift and is referred to as glacial till or boulder clay. The glacial drift occurs in several forms:

(1) Ground Moraine. A boulder clay or till plain (includes areas where the glacial drift is very thin and the surface uneven).

(2) Terminal Moraine or Moraine. A hilly tract of country formed by glacial drift that was laid down at the margin of the continental ice-sheet during pauses in its retreat. The surface is characterized by irregular hills and undrained basins.

(3) Glacial Outwash. Sand and gravel plains or deltas formed by streams that issued from the continental ice-sheet.

(4) Glacial Lake Deposits. Sand and clay plains formed in glacial lakes during the retreat of the ice-sheet.

Ground Water. Sub-surface water, or water that occurs below the surface of the land.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it is first encountered.

Impervious or Impermeable. Beds, such as fine clays or shale, are considered to be impervious or impermeable when they do not permit of the perceptible passage or movement of ground water.

Pervious or Permeable. Beds are pervious when they permit of the perceptible passage or movement of ground water, as for example porous sands, gravel, and sandstone.

Pre-Glacial Land Surface. The surface of the land before it was covered by the continental ice-sheet.

Recent Deposits. Deposits that have been laid down by the agencies of water and wind since the disappearance of the continental ice-sheet.

Unconsolidated Deposits. The mantle or covering of alluvium and glacial drift consisting of loose sand, gravel, clay and boulders that overlies the bedrock.

Water-table. The upper limit of the part of the ground wholly saturated with water. This may be very near the surface or many feet below it.

Wells. Holes sunk into the earth so as to reach a supply of water. When no water is obtained they are referred to as dry holes. Wells in which water is encountered are of three classes.

(1) Wells in which the water is under sufficient pressure to flow above the surface of the ground.

(2) Wells in which the water is under pressure but does not rise to the surface.

(3) Wells in which ~~the water does~~ not rise above the water-table.

BEDROCK FORMATIONS OF EAST-CENTRAL ALBERTA

The formations that outcrop in east-central Alberta are of Tertiary and Upper Cretaceous age, and consist entirely of relatively soft shales and sandstones, with some bands of hard sandstone and layers of ironstone nodules. The succession, character, and estimated thickness of the formations are shown in the following table:

Age	Formation	Character	Thickness
			Feet
Tertiary	Paskapoo	Light grey sandstone, in part carbonaceous; shale; small amounts of siliceous limestone and volcanic dust; coal seams.	800 ±
Upper Cretaceous	Edmonton	Grey to white, bentonitic sands and sandstones, with grey and greenish shales; coal seams prominent in some areas, as at Drumheller.	1,000 to 1,150
	Bearpaw	Dark shales, green sands with smooth, black chert pebbles; partly non-marine, with white bentonic sands, carbonaceous shales, or thin coal seams similar to those in Pale Beds; shales at certain horizons contain lobster-claw nodules and marine fossils; at other horizons selenite crystals are abundant.	300 to 600
	Pale and Variegated Beds	Light grey sands with bentonite; soft, dark grey and light grey shales with selenite and ironstone; carbonaceous shales and coal seams; abundant selenite crystals in certain layers.	600 ±
	Birch Lake (?)	Grey sand and sandstone in upper part; middle part of shales and sandy shales, thinly laminated; lower part with grey and yellow weathering sands; oyster bed commonly at base.	100 ±
	Grizzly Bear	Mostly dark grey shale of marine origin, with a few minor sand horizons; selenite crystals and nodules up to 6 or 8 inches in diameter.	100 -
	Ribstone Creek	Grey sands and sandstones at the top and bottom with intermediate sands and shales; mostly non-marine, but middle shale in some areas is marine.	325 -

WATER ANALYSES

Introduction

The following discussion of water analyses is included to assist those who wish to know the effect of various mineral constituents in well water, which give the water in some wells certain peculiar qualities.

Discussion of Chemical Determinations

The dissolved mineral constituents vary with the material encountered by the water in its migration to the reservoir bed. The mineral salts present are referred to as the total dissolved solids, and they represent the residue when the water is completely evaporated. This is expressed quantitatively as "parts per million", which refers to the proportion by weight in 1,000,000 parts of water. A salt when dissolved in water separates into two chemical units called "radicals", and these are expressed as such in the chemical analyses. In the one group is included the metallic elements of calcium (Ca), magnesium (Mg), and sodium (Na), and in the other group are the sulphate (SO_4), chloride (Cl), and carbonate (CO_3) radicals.

Mineral Constituents Present

Calcium (Ca) in the water comes from mineral particles present in the surface deposits, the chief source being limestone, gypsum, and dolomite. Fossil shells provide a source of calcium, as does also the decomposition of igneous rocks. The common compounds of calcium are calcium carbonate ($CaCO_3$) and calcium sulphate ($CaSO_4$).

Magnesium (Mg) is a common constituent of many igneous rocks and, therefore, very prevalent in ground water. Dolomite, a carbonate of calcium and magnesium, is also a source of the mineral. The sulphate of magnesium ($MgSO_4$) combines with water to form "Epsom salts", and if present in large amounts imparts a bad taste and is detrimental to the health.

Sodium (Na) is derived from a number of important rock-forming minerals, so that sodium sulphate and carbonate are very common in ground waters. Sodium sulphate (Na_2SO_4) combines with water to form "Glauber's salts", which if present in amounts over 1,200 parts per million makes the water unfit for domestic use or for irrigation. Sodium carbonate (Na_2CO_3) or "black alkali" waters are mostly soft, the degree of softness depending upon the ratio of sodium carbonate to the calcium and magnesium salts. Waters containing sodium carbonate in excess of 200 parts per million are unsuitable for irrigation.

Chlorine (Cl) is, with a few exceptions, expressed as sodium chloride (NaCl), which is common table salt. When found in water in excess of 400 parts per million it renders the water unfit for domestic use.

Iron, when present in more than 0.1 parts per million, will settle out of the water as a red precipitate on exposure to the air. Water that contains not more than 0.5 parts per million

is considered the usual upper limit for potable water, but this amount is often exceeded. A water that contains considerable iron will stain porcelain, enamel ware, and clothing that is washed in it, but the iron can be almost completely removed by aeration and filtration of the water.

Hardness. Hardness is of two kinds, temporary and permanent. Temporary hardness is caused by calcium and magnesium bicarbonates, which are soluble in water but are precipitated as insoluble normal carbonates by boiling, as shown by the scale that forms in teakettles. Permanent hardness is caused by the presence of calcium and magnesium sulphates, and is not removed by boiling. Waters grade from very soft to very hard, and can be classified according to the following system[1].

[1] The "Examination of Waters and Water Supplies"; Thresh and Beale, Fourth Ed. 1933, p. 21.

A water under 50 degrees (that is, parts per million) of hardness may be said to be very soft.

A water with 50 to 100 degrees of hardness may be said to be moderately soft.

A water with 100 to 150 degrees of hardness may be said to be moderately hard.

A water with more than 200 and less than 300 degrees of hardness may be said to be hard.

A water with more than 300 degrees of hardness may be said to be very hard.

Hard waters are usually high in calcium carbonate. Almost all of the waters from the glacial drift are of this type, particularly those not associated with sand and gravel deposits that come close to the surface.

In soft water the calcium carbonate has been replaced by sodium carbonate, due to natural reagents present in the sands and clays. Bentonite and glauconite are two such reagents known to be present. Montmorillonite, one of the clay-forming minerals, has the same property of softening water, owing to the absorbed sodium that is available for chemical reaction.[2]

[2] Piper, A.M.: "Ground Water in Southern Pennsylvannia", Penn. Geol. Surv., 4th series.

If surface water reaches the lower sands by percolating through the higher beds it may be highly charged with calcium salts before reaching the bedrock formations containing bentonite or glauconite. The completeness of the exchange of calcium carbonate for sodium carbonate will, therefore, depend upon the length of time that the water is in contact with the softening reagent, and also upon the amount of this material present. The rate of movement of underground water will, consequently, be a factor in determining the extent of the reaction.

TOWNSHIPS 31 TO 34, RANGES 25 TO 29,
WEST FOURTH MERIDIAN, ALBERTA

Introduction

The investigation of ground-water resources in Alberta was continued during the summer of 1949 by the writer, ably assisted by P. J. S. Byrne. The surface deposits were also mapped, and the relation of both the surface deposits and the underlying bedrock to the ground-water supply studied.

Physical Features

Several valleys, as much as 300 feet deep and with gradients of 7 to 15 feet to a mile, trend south or southeastward through the area. The two largest are occupied by Threehills and Kneehills Creeks, but those of Spruce and Lonepine Creeks are also large. Several dry valleys 50 to 150 feet deep and some smaller ones are present in the west. Threehills and Kneehills Valleys are several miles wide and have gently-sloping valley walls, whereas the other valleys are narrow and steepsided. Lakes and ponds, commonly a mile long, are present, chiefly in the south-centre of the area. Most of these lie in valleys that have been dammed by drift, such as Davey Lake, or locally deepened by glaciation, such as Stewart Lake.

The highest altitudes in the area, over 3,350 feet, are about 5 miles northwest of Wimborne, and much of the west and northwest part of the township is over 3,300 feet. The surface generally falls eastward and southeastward to about 3,000 feet, and Threehills and Kneehills Creeks leave the area at about 2,800 feet above sea-level. This general trend is interrupted by the Kneehills, which rise to 3,250 feet above sea-level and have a surprisingly flat summit several miles in extent. Other hills 5 miles east of Sunnyslope also rise above 3,250 feet. Some hills and ridges are also present in the east and north. Local relief greater than 300 feet is common.

Except for the valleys and several long, narrow, low ridges, the southwest part of the area is almost monotonously flat. The north and northeast is generally characterized by broadly rolling hills and ridges, and in the southeast broad hills and valleys are common. The topography is almost entirely a reflection of the bedrock, and is a little modified by drift.

Geology

Almost the entire area has a mantle of glacial deposits or alluvium. The underlying bedrock is Paskapoo formation, but the Edmonton formation, although below the Paskapoo and probably more than 500 feet deep in the western part of the area, comes close to the surface in the southeast. Older formations, mentioned in the table on page 4, underlie the Edmonton, but as they are not less than 1,200 feet deep, they are too deep to affect surface features or water supply. The common dip of bedrock is west or southwest, and, as the land surface also rises in that direction, the Paskapoo is thicker there, and beds younger than those in the east are present. Bedrock is exposed along several stream valleys and particularly in road ditches crossing hills and ridges in the southeast.

Edmonton Formation. The name Edmonton was first applied to the beds containing coal in the Edmonton area, and later to the same beds in adjoining areas. The formation has a total thickness of 1,000 to 1,150 feet, but is bevelled off eastwards, and the eastern edge of the formation follows a northwest line from Coronation through Tofield to a point on North Saskatchewan River about midway between Edmonton and Fort Saskatchewan. No Edmonton beds occur northeast of this line, but as the formation dips to the southwest it becomes progressively thicker in that direction.

The Edmonton formation consists of poorly bedded, grey and greenish grey clay shale, coal seams, and sand and sandstone that

contain clay and white material known as bentonite. Bentonite when wet is very sticky and swells greatly in volume and when dry tends to whiten the beds containing it. Such beds are relatively impervious to water, and at the surface produce the "burns" of barren ground where vegetation is scanty or absent.

Paskapoo Formation. This formation was first named by Tyrell from exposures of the lower part of the formation along Blindman River near its confluence with the Red Deer. It is composed essentially of sandstone and shale deposited in fresh water and includes some thin coal seams and carbonaceous beds. The basal beds are massive, crossbedded sandstone that weathers buff-yellow, and are in striking contrast to the underlying, light-coloured, bentonitic clay of the Edmonton formation. About 150 to 200 feet above the base of the formation are a series of lenses of siliceous limestone containing fossil gastropods and pelecypods.

Unconsolidated Material. During Pleistocene or Glacial time, great accumulations of ice formed at various centres in northern Canada. This ice moved out in all directions from these centres and covered large regions with what has been called the continental ice-sheet. As the ice advanced, it picked up great quantities of loose rock debris that was laid down when the ice finally melted. This material is unconsolidated, and is commonly called glacial drift.

The present area was entirely covered by one or more continental ice-sheets during Pleistocene time, and the final retreat of the ice left the bedrock buried to various depths by glacial drift. Most of the drift consists of boulders and pebbles of various compositions and sizes embedded in a matrix of clay or sandy clay to form a more or less impervious mass known as boulder clay or till. Irregularly intermingled with this till and also lying above it, are beds, pockets, and lenses of sand and gravel

that form the water-bearing members or aquifers.

The character of the till changes gradually from east to west. In the east it is a brownish or yellowish colour and contains much clay, little sand, and few stones. It is very sticky and contains much material derived from the Edmonton formation. In the west, as it contains more material from the Paskapoo formation, it is brownish, yellowish, or reddish coloured and, although it also contains much clay, it is more sandy and is slightly less sticky than that in the east. It contains more stones, chiefly of quartzitic material gathered by the ice from gravel carried by rivers flowing eastward from the Rocky Mountains, although pockets of gravel are uncommon.

The unconsolidated material is rarely more than 20 feet thick, and its average thickness is probably less than 15 feet. It is thickest in the areas of end moraine in the northeast, but even there is not as thick as would at first appear as the moraine commonly overlies rises in bedrock.

Ground Moraine. This type of drift is chiefly till or boulder clay laid down beneath the ice-sheet. It commonly has a flat or gently rolling surface, and has a tendency to lessen the relief of the underlying bedrock surface. Ground moraine covers about 435 square miles, or most of the area.

End Moraine. Part of the material carried by the ice-sheet is dropped at its front or margin during pauses in the general retreat of the melting glacier. It consists of till, silt, sand, and gravel gathered during the advance of the ice-sheet. Much of the clay, silt, and fine sand may have been carried away by melt-water from the glacier, and the material forming end moraine is commonly coarser than that forming ground moraine, and may consist mainly of gravel, sand, and coarse till, characteristically arranged in hummocks and undrained or poorly drained hollows. In the area

being discussed, however, the material of the end moraine is not noticeably coarser than that of the ground moraine. About 85 square miles, chiefly in the northeast, is covered with the typical ridges, hills, and depressions of weakly developed, clayey, end moraine.

Glacial-lake Sediments. During the melting back of the ice-sheet many lakes were formed where the normal drainage was temporarily blocked by lobes of ice or masses of glacial debris. Sand, silt, and clay were washed into these lakes and there laid down. Draining or lowering of these lakes exposed this material in discontinuous patches here and there throughout the area. Similar, although commonly coarser, material was laid down by streams draining these lakes, by streams from the melting ice, or by recent streams. The original sediments have been attacked by wind and much of the material redistributed by this agent. Sediments of these latter types affect water supply in much the same manner as do the glacial-lake sands, from which most of them are practically indistinguishable. Scattered patches of glacial-lake beds cover about 65 square miles of the area, of which 30 square miles consist of impervious lake clay or silt in the valleys of Kneehills and Threehills Creeks. North of Sunnyslope duned sand covers about 10 square miles.

Patches of stream and glacial-outwash gravel cover more than 9 square miles, and bedrock is shallow in areas totalling 3 or 4 square miles. These areas are mentioned in the descriptions of the various townships.

Water Supply

Sufficient water for ordinary farm and town use can be obtained anywhere in the area. The quality is generally good, as shown by chemical analysis of representative samples given later.

The average depth of drilled wells in the area is about 107 feet, slightly less in the north. The average depth of dug

wells is about 25 feet. The water is always under pressure, and rises one-third to two-thirds of the distance to the surface. Springs occur along some valleys, and several flowing wells are present, particularly near Lonepine Creek in the west.

The area has a semi-arid climate and the average yearly precipitation ranges from about 14 to 19 inches, being greatest in the west and north, and least in the southeast. One-quarter to one-third of the precipitation is in the form of snow. In the southwest and southeast the run-off is rapid as the drainage is fairly good, the vegetation light, and much of the soil nearly impermeable clay. Furthermore, as the humidity is generally low and the summers are warm, the rate of evaporation is high. In much of the north and south-central parts of the area, particularly in that part covered by end moraine, drainage is poor, there are more trees and other vegetation, the surface material is commonly more permeable, and the run-off is slower and smaller than in the southwest and southeast. A much greater proportion of the precipitation, therefore, seeps into the drift and bedrock in the north, northeast, and south-central parts than in the southwest and southeast. For these reasons, and also because the total precipitation is greater in the former regions, there is more ground water available there than in the southwest and southeast. Thus, although sufficient water for farm and domestic use is available anywhere, large supplies are easily obtainable only in the north.

No dependable sources of surface water are present, for the creeks, such as Threehills, Kneehills, Spruce, and Lonepine, are small and nearly dry during much of the summer, and the lakes and ponds become low and rather alkaline in dry years.

A few wells draw generally fair or sufficient supplies of water from aquifers in glacial-lake sands, dune sand, outwash and

stream gravel or alluvium, and end moraine. An adequate supply of water is unlikely to be obtained from the ground moraine, which covers most of the area, or from the lake clay and silt in Threehills and Kneehills Valleys. Most of the water found in the drift contains much calcium and is hard and may also contain noticeable amounts of iron.

Of the 528 wells recorded, 508 draw from bedrock aquifers, 2 of these in the southeast from Edmonton formation and the others from the Paskapoo. All but 70 of the bedrock wells are drilled. About 14 of the 20 non-bedrock wells are dug into glacial drift and 6 are in recent material. In thirteen of the twenty townships no non-bedrock wells are recorded.

The Edmonton formation contains many isolated lenses of sand irregularly distributed throughout the formation. Some zones contain more of these lenses than others and, as the water is in the sand, these zones are the more likely to yield water. Water is also frequently found either above or below coal seams. The Edmonton aquifers are used only in the southeast, where the formation is shallowest, but even in the eastern half of the area it is a potential source of soft water for deep drilling. Although this formation contains much water, the generally small grain size of the material composing it does not allow it to yield this water quickly.

Water entering the Edmonton beds through the overburden is usually charged with calcium carbonate and is hard, but sodium carbonate from the Edmonton formation replaces the calcium carbonate, softening the water. Generally the longer water is in contact with the Edmonton formation the softer it becomes, and although hard or moderately hard water may occur near the surface of the Edmonton, farther down practically all the water is soft. Sodium carbonate is the principal mineral matter found in water from the Edmonton formation along with small amounts of iron in places and some carbonaceous material from near coal seams.

The Paskapoo formation generally contains abundant water, mostly in porous sand lenses that are more common in some horizons of the formation than in others. None of these lenses can be traced far, but in most places they overlap and form aquifer zones each of which has water with distinguishing characteristics. In this area, each zone becomes deeper westward and finally can be traced no farther in that direction. The sand of the Paskapoo formation is commonly coarse and will yield water quickly. This is particularly characteristic of the area being discussed. As much of the Paskapoo formation is unconsolidated, trouble is experienced with sand and silt entering wells and reducing the water supply. Well screens are not used in the area, but might prove practicable in some wells.

The water contained in the Paskapoo formation in this area varies greatly in quality, but generally contains much calcium carbonate, indeed some of the water is too hard for ordinary washing. Of the wells into Paskapoo recorded in this area, 216 yield hard water, and 280 soft or moderately hard water. Much of the water from the Paskapoo contains some iron, and the very hard water may contain a great deal of it, in some wells, indeed, the water cannot be used on this account. As the soft water of the area contains much soda, aluminium or magnesium casing should not be used in wells of this type.

In the well record sheets at the end of the report, and in the descriptions of the various townships, the terms poor, insufficient, fair, sufficient, good, very good, and excellent are used to describe the water supply. Poor or insufficient is used if enough water for ordinary farm needs, perhaps 500 gallons a day, cannot be obtained from the well. The term fair supply is used if enough water for such needs can be obtained, generally more than 1,000 gallons a day, but only by slow pumping or by pumping small amounts several times a day. Sufficient supply

indicates that enough water is available, but that little information could be obtained upon the amount used. Good supply is used if the well does not go dry under ordinary farm demands, and enough water for farm needs with some to spare can be obtained at one pumping. Such wells can generally yield more than 2,000 or 3,000 gallons a day. Very good supply means that no trouble has ever been experienced in obtaining sufficient water and that at least 5,000 to 15,000 gallons a day should be available. Excellent supply is used if the amount of water available is exceptionally good.

Township 31, Range 25. Kneehills Creek flows southeastward through the southwest corner of the township at about 2,285 feet above sea-level. The land rises to the north and east, and some hills in the southwest are higher than 3,250 feet in elevation. The topography is mainly that of broad, smooth, bedrock hills, little modified by drift, but cut by valleys and gullies of recently developed drainage.

A thin, flattish mantle of ground moraine covers most of the township, but in the west it is commonly overlain by sand, laid down chiefly as alluvium and outwash and in some places later duned by wind. Bedrock outcrops on some hills and in some gullies, but the average thickness of drift is probably 10 to 15 feet.

Only one of the thirty wells recorded obtains water from unconsolidated material. The sand in the west can supply some water, but, as the till is thin and relatively impervious, none can be obtained from the ground moraine. The water in the unconsolidated material is hard and in poor to fair supply only. Furthermore, the wells are difficult to maintain.

Of the twenty-nine Paskapoo bedrock wells, twenty-eight are drilled, and these are 45 to 200 feet deep with an average depth of about 100 feet. The amount of water in practically all is good, and 60 per cent yield soft water. They tap aquifers between 2,820

and 3,080 feet above sea-level, but mostly between 2,900 and 3,000 feet. Hard and soft water aquifers are intermingled. The water has some pressure, but its rise in the wells is generally negligible or slight.

Although the Edmonton formation is 200 to 500 feet below the surface, it is everywhere a potential source of soft water for deep drilling. In general, ample water, soft if desired, may be found anywhere in the township.

Township 31, Range 26. Kneehills Creek flows southeastward through a large valley across the northeast quarter of the township. Lonepine Creek flows southeastward across the southwest corner. A third valley, marked by a string of lakes, trends southeast from the northwest corner. Except for these valleys, and sand hills in the northeast, the surface is practically flat. Several lakes are present, but these usually become low in the autumn.

Ground moraine covers more than half the township. In the northeast alluvial sand, partly reworked by wind to form dunes, commonly overlies the ground moraine and some low morainal hills. Sand, silt, and clay occur along the three valleys mentioned above, and gravel is also present along Lonepine Creek. A thin layer of lake sand is present in the southwest.

The unconsolidated material probably does not average much more than 10 or 12 feet in thickness, and is not important for water supply. Of the twenty-seven wells recorded only five, all in sand or gravel areas and mostly in the wind-blown sand, tap aquifers in these deposits. The water of all five is hard and in fair to good supply. Any attempt to find water in the ground moraine is ill-advised.

Eighty per cent of the wells enter bedrock, and most of these are drilled. The latter are 55 to 225 feet deep, with an average depth of 110 feet. They tap aquifers between 2,735 and 3,070 feet above sea-level, but chiefly between 2,805 and 2,965 feet. The lowest aquifer, at 2,737 feet, is probably in the

Edmonton formation, which, although it does not outcrop and is at a general depth of 200 to 300 feet, is everywhere a potential source of soft water. The other aquifers are in the Paskapoo formation. This formation underlies the unconsolidated material everywhere and outcrops along Kneehills Creek and beside some lakes, in the southeast of section 29 for example. The quantity of water is generally good, and the water is under pressure and rises one-half to four-fifths of the distance to the surface. Soft and hard water aquifers alternate, and one-third of the wells yield soft or moderately hard water and the remainder hard.

In general, ample water, mostly hard, can be obtained at reasonable depth anywhere in the township.

Township 31, Range 27. Lonepine Creek flows eastward in a shallow valley, and is joined near the centre of the township by another valley, now dry. Other major topographic features are lacking.

A mantle of ground moraine, probably averaging 15 feet in thickness, covers most of the township. The surface of this is practically flat except for a few morainal ridges 10 to 30 feet high and several miles long. Five to ten feet of coarse gravel with a very flat surface covers about 5 square miles along the dry valley in the northwest part of the township and some lake sand is present in the southeast corner. Several shallow wells draw hard water from the gravel, but no water can be obtained from the ground moraine.

The Paskapoo formation underlies the unconsolidated material everywhere but rarely outcrops, and 95 per cent of the wells recorded enter it. All but two of the bedrock wells are drilled, and these are 60 to 170 feet deep with an average depth of about 120 feet. They use aquifers from 2,895 to 3,100 feet above sea-level, and many tap aquifers near 2,950 feet. Soft-water aquifers are interposed with hard-water ones, and the same

aquifer may yield hard water to one well and soft to another some distance away. About 60 per cent yield soft or moderately hard water. The supply is generally good except in those wells being filled with silt, in which it is commonly insufficient. Most of the water is under enough pressure to force it nearly to the surface, and one flowing well is recorded.

In general, ample water is available in the bedrock at moderate depth anywhere in the township.

Township 31, Ranges 28 and 29. Several low, morainal ridges offer some relief to an otherwise flat and featureless surface that slopes slightly down towards Lonepine Creek in the northeast corner of the township.

Ground moraine 10 to 30 feet thick covers the entire township, except for a few ridges of end moraine 20 to 50 feet high and ½ mile to 3 miles long. The worthlessness of the ground moraine for water supply is indicated by the fact that not one of the seventy three wells recorded taps aquifers in it, and any attempt to obtain water from the drift is ill-advised.

The unconsolidated material is underlain by the Paskapoo formation, which contains much water. Aquifers in it are particularly numerous in this region, perhaps reflecting a greater than usual proportion of sandstone and less clay. All the wells are drilled into this formation, and are 15 to 250 feet deep, with an average depth of 105 feet in range 28 and 140 feet in range 29. They tap aquifers between 2,845 and 3,195 feet above sea-level, but mostly above 3,000 feet. The water in the lower aquifers is commonly softer than that in the higher. More than half the wells yield soft water and another fifth moderately hard water. The quantity in practically all wells is good to very good. The water is under much pressure, and in five wells rises to or above the surface. The rise is greatest in sections 21, 26, 27, 28, 30, 34, 35, 36, range 28, or in the vicinity of a valley tributary to Lonepine Creek.

In general, the Paskapoo formation yields ample, mostly soft water under strong pressure at moderate depth anywhere in these townships.

Township 32, Range 25. The Knee Hills, which cover more than half the township, are the chief topographic feature. In the west they form a flat-topped strath at more than 3,200 feet above sea-level. In the southwest also they rise above 3,200 feet, and at lower elevations they cover the centre of the township. From Kneehills the surface slopes east and northeast to below 2,850 feet in the northeast corner of the township. Several gullies drain in this direction into Threehills Creek. The topography reflects bedrock features that are little modified by drift.

A flat mantle of ground moraine, with an average thickness of perhaps 10 feet, covers most of the township. Bedrock is exposed near the surface on Knee Hills and in some gullies. Lake clay, a continuation of the body laid down in Threehills Creek Valley, covers several square miles in the northeast. The fact that probably none of the wells examined draws water from them, indicates that the ground moraine and lake clay is too thin and too impervious to hold satisfactory supplies of water.

Of the 21 bedrock wells recorded, 17 are drilled, 32 to 200 feet deep, with an average depth of 90 feet. As the surface has much relief, aquifers between 2,790 and 3,130 feet above sea-level are used, but most wells tap aquifers between 2,790 and 2,955 feet. The water is under pressure and rises in the wells, but the depth to water is extremely variable because of the broadly rolling nature of the surface. The quantity of water in all wells is good to very good. In more than half the water is soft, although no particular soft-water zones in the bedrock are apparent.

Sufficient good water for ordinary farm use, and in places large amounts, is obtainable anywhere in this township at rather shallow depth.

Township 32, Range 26. Kneehills Creek flows southward in a valley 3 miles wide and more than 150 feet deep. Spruce Creek, in a valley equally deep but narrower, joins it near the centre of the township. In the east the broad Kneehills, composed largely of bedrock, rise 350 feet above the valleys. The surface in the southeast is rolling, in the southwest fairly flat, and in the northwest rolling with many small hills.

A thin mantle of ground moraine covers 9 square miles of the northeast part of the township and 8 of the southwest. Lake and stream alluvium, mostly sand and commonly duned by wind, covers the valleys except where outwash gravel and end moraine occur on the south side of Spruce Creek. The unconsolidated mantle probably averages 15 to 20 feet in thickness, being thicker in areas of end moraine and thinner in ground moraine.

Some water is available in the end moraine and sand, but little can be expected in the ground moraine. In general, the water in the surficial material is hard and the wells are difficult to maintain. Bedrock aquifers are a more attractive source of water.

The Paskapoo formation underlies the unconsolidated mantle throughout the township and contains the aquifers tapped by most of the wells. These wells are 50 to 250 feet deep, and average about 140 feet in depth. They tap aquifers between elevations of 2,810 and 3,085, but mostly between 2,810 and 2,950 feet. The quantity of water in each well is satisfactory, and in 80 per cent the water is soft or moderately hard. A single aquifer may, however, yield soft water in one place and hard in another. The water is under pressure and generally rises one-half to two-thirds of the distance to the surface. Springs are present along the valleys.

Large amounts of water, generally soft, can be obtained at moderate depth in the bedrock practically anywhere in the township.

Township 32, Range 27. Spruce Creek crosses the northeast corner of the township in a narrow, steep-sided valley as much as 250 feet deep. A large valley, now dry except for several lakes, trends southeast to the southeast corner, and a shallow valley crosses the extreme southwest corner of the township. These valleys are the chief topographic features. The land in the northeast is markedly rolling, but elsewhere, except for several long, narrow ridges, the land is flat to gently rolling.

South of Spruce Creek outwash gravel and end moraine forming knob and kettle topography cover 3 square miles. In other places linear end moraines, 10 to 40 feet high and $\frac{1}{2}$ mile to 5 miles long, are present. Gravel beds, 5 to 10 feet thick and flat surfaced, cover about 1 square mile of the southwest. Over the remainder of the township bedrock is covered by ground moraine. The unconsolidated cover has an average thickness of perhaps 15 feet, and is thickest in areas of end moraine.

Of the wells examined only three, in end moraine or the more sandy ground moraine, draw water from unconsolidated materials. This water is hard and in only fair supply. Although the gravel in the southwest, the end moraine, and the sandy ground moraine will yield water, most of the ground moraine contains little, and the use of bedrock aquifers is everywhere advisable.

Paskapoo formation underlies the drift throughout the township and most wells are drilled into it. They are from 20 to 262 feet deep, with an average depth of 110 feet, and tap aquifers between 2,910 and 3,145 feet above sea-level. They generally supply a fair to good quantity of water, but quicksand commonly causes trouble and deepening would improve those with poor supplies. The wells are fairly equally divided between those that produce soft, moderately hard, and hard water; those that tap the lower aquifers generally yield the softer water. The water commonly contains

noticeable iron, and in some cases in large amounts. The water is under pressure, and its rise in the wells, although variable, is mostly high, particularly so in the south and west.

In general, sufficient water for ordinary farm use is available anywhere at moderate depth in the bedrock, and very large supplies are commonly available.

Township 32, Ranges 28 and 29. Lonepine Creek flows southward through the centre of the township in a very small valley. A second shallow but wider valley parallels Lonepine Creek through the eastern part. A few low ridges, some several miles long, are present near Lonepine Creek, but otherwise these townships are relatively flat and without any striking topographical feature.

Ground moraine covers both townships, except for some gravel and sand along the easterly of the two valleys, and several small, linear end moraines. The unconsolidated cover is thin, particularly in the southeast, and probably does not average much more than 15 feet in thickness. Bedrock outcrops or is close to the surface near some of the valleys. The drift is too thin, and the ground moraine is too impervious to be of any value for water supply, and none of the wells recorded obtains water in them.

The Paskapoo formation underlies the drift and most wells are drilled into it. These wells are 55 to 230 feet deep, with an average depth of 125 feet in range 28 and 135 feet in range 29. They tap aquifers between 2,905 and 3,160, but mostly from 3,040 to 3,160 feet above sea-level. The supply practically everywhere is good to very good, and the few wells with insufficient water could be improved by deepening. Although no aquifer yields the same kind of water everywhere, the water in 60 per cent of the wells is soft. Most of the water contains noticeable iron, and some water a great deal of it. As the water is under considerable pressure, it commonly rises high, and flowing wells, several with excellent flow, are present in the low land drained by Tenmile Creek in sections 17 and 18 of range 28, and 13 and 24 of range 29.

Ample water for farm or town use, mostly soft, is generally available at moderate depth in the bedrock anywhere in these townships.

Township 33, Range 25. Threehills Creek flows south down the east side of the township, and its valley, 3 or 4 miles wide and as much as 200 feet deep, is the chief feature of the township. The valley floor is almost flat, but elsewhere the surface of the township is rolling with a general slope down towards Threehills Creek. Here and there it is cut by gullies, and broad bedrock hills or smaller ones of drift rise above the general level. Trees are present in the northern part of the township, but the tree limit runs through the township and in the southern part they are absent.

Low end moraine, with knobs rising 20 or 30 feet above the kettles, covers more than half the township. Lake clay forms a fairly flat surface in 8 square miles of Threehills Valley and gravel is present in sections 3, 4, 5, 9, and 10. A mantle of ground moraine, not thick enough to mask entirely irregularities in the top of the underlying bedrock, covers the rest of the township. The surficial material, of which the end moraine is thickest, averages perhaps 15 feet in thickness. The lake clay yields no water, and the ground and end moraine, although they contain patches of sand, are so thin that bedrock aquifers are a more reliable source of water. None of the wells recorded obtains water from the drift.

The Paskapoo formation underlies the drift and supplies all the water used. The Edmonton formation, which underlies the Paskapoo at depths of 200 to 400 feet, is a potential source of soft water for deep drilling. The drilled wells are 50 to 176 feet deep, with an average depth of 100 feet, and tap aquifers between 2,685 and 3,050 feet above sea-level, but mostly between 2,775 and 2,825, 2,850 and 2,895, and 2,980 and 3,020 feet. The

lower aquifers supply hard to very hard water to about 70 per cent of the wells. The moderately hard and hard water generally contains noticeable to much iron that gives a strong iron taste. Practically all wells have ample water, under sufficient pressure in the east to rise nearly to the surface but with practically no rise in the west.

In general, sufficient water for ordinary farm use is available from the bedrock anywhere in the township, and larger amounts can be obtained. However, the quality may not be as good as desired.

Township 33, Range 26. Kneehills Creek flows southward along the west side of the township through a flat-floored valley several miles wide and 200 feet deep. The rest of the township is marked by broad, bedrock hills and ridges, and lesser, rolling, morainal hills. The surface rises from Kneehills Creek eastwards towards Wimborne.

Knob and kettle end moraine, with hills as much as 30 feet high, covers 15 square miles in the northeast, and lake clay covers about 9 square miles of Kneehills Valley. Elsewhere, ground moraine, too thin to hide the irregularities of the underlying bedrock surface, covers the township. The drift, which is thickest in areas of end moraine, has an average thickness of perhaps 15 to 20 feet. The lake clay and ground moraine yield no water, but the end moraine contains sandy lenses that may yield fair amounts. However, as the drift is thin, bedrock is a more certain source of water, and none of the wells examined tapped aquifers in the overburden.

As the Edmonton formation is 400 to 600 feet deep, its soft water is not easily available in this township, and all the wells enter the Paskapoo formation, which directly underlies the drift. The drilled wells are 40 to 235 feet deep, with an average depth of 95 feet, and tap aquifers between 2,905 and 3,120 feet above sea-level, but chiefly from 2,945 to 3,035, and 3,070 to 3,120 feet. Half the wells yield hard water, the others moderately hard or soft. The water from above 3,070 feet is chiefly hard to

very hard and contains noticeable, to much, iron, whereas water from the lower aquifers is generally softer and contains less iron. The quantity of water in all the wells is fair to good, and the water is generally under enough pressure to rise more than half the distance to the surface. Two shallow wells, dug into bedrock, flow and yield large quantities of hard water.

Township 33, Range 27. A dry valley about 1 mile wide and 200 feet deep in the western part of the township is the chief topographic feature. Elsewhere the surface is more or less flat but slopes downward in the east towards Kneehills Creek.

Ten to fifteen feet of a sticky, clayey, grey or brown, relatively stoneless ground moraine covers all the township except in the dry valley where bedrock is near the surface. As it is thin and contains much clay any attempt to obtain water from the drift is ill-advised, and no wells use aquifers in it.

The Paskapoo formation underlies the surficial material and is the only potential source of water. All wells tap aquifers in it. Only 4 of the 37 wells recorded are dug, and the 33 drilled wells are 38 to 210 feet deep, with an average depth of 105 feet. They tap aquifers distributed fairly evenly between 2,925 and 3,225 feet above sea-level. Soft-water aquifers are alternated with those yielding hard water, about half the wells yielding hard water and the others moderately hard or soft. Iron is noticeable in the water from about half the wells. The only two wells have insufficient water, and these are shallower than the average and would be improved by deepening. The water is mostly under enough pressure to raise it one-third to two-thirds of the distance to the surface.

In general, ample water for farm and domestic use, and probably in most places also for town use or other large requirements, is available at moderate depth in the bedrock.

Township 33, Ranges 28 and 29. A narrow, dry valley, about 150 feet deep, that for several miles is divided into two parallel branches, trends southeastward through the centre of range 28. Except for this valley, only a few low, scattered ridges break the monotony of the flat and featureless townships.

Except for the valley where bedrock is near the surface and a few ridges of end moraine perhaps 20 feet high and as much as 3 miles long, ground moraine covers these townships. East of the valley this material has an average thickness of about 7 feet, and west of it a thickness of about 10 or 12 feet, as it is thin and generally contains much clay, any attempt to obtain water from it is inadvisable. The only well that does not enter bedrock draws a good supply of hard water from a local pocket of gravel in sec. 23, rge. 28.

The Paskapoo formation underlies the drift and supplies practically all the water used. The drilled bedrock wells are 45 to 240 feet deep, with an average depth of 105 feet in range 28 and 115 in range 29. They tap aquifers between 2,980 and 3,240 feet above sea-level, but particularly in the zones between 3,010 and 3,030 feet, 3,100 and 3,175 feet, and 3,205 and 3,240 feet. About two-thirds of the wells yield soft or moderately hard water, the others hard to very hard, and the water from about one-third has noticeable amounts of iron. The amount of water from all these drilled wells is sufficient for ordinary farm use, and the water generally has enough pressure to raise it half the distance to the surface. One flowing well is recorded near Lonepine Creek and others could be found in the same locality, as in the townships to the north.

An interesting feature of these townships, and of those to the north, is the large number of rather similar wells dug into bedrock. Ten wells of this type are recorded and others are undoubtedly present. They average 30 feet in depth and yield hard or

moderately hard water in which iron is seldom noticeable, the quantity being generally sufficient for farm use. They use aquifers between 3,180 and 3,280 feet above sea-level, but mostly from 3,180 to 3,195 feet, a zone from which no drilled well obtains water. The water level of these dug, bedrock wells falls in dry years.

In general, large amounts of good water can be obtained, at comparatively shallow depth, in the bedrock anywhere in these townships.

Township 34, Range 25. Threehills Creek flows southeastwards from corner to corner across this township and, although only a small stream, it occupies a flat-floored valley several miles wide and 100 to 150 feet deep that is the chief topographic feature of the township. The surface elsewhere is rough, with broad, bedrock hills and ridges commonly overlain by smaller, rolling drift knolls 20 to 50 feet high. Gullies are present near the creek.

An almost flat mantle of lake clay and silt covers 6 square miles of the valley floor. Knob and kettle end moraine, with hills perhaps 20 feet high, covers about 7 square miles of the southwest and nearly 11 square miles in the north. The end moraine crosses Threehills valley in a strip about $\frac{1}{2}$ mile wide through which the creek flows with a winding course and steep gradient. The eastern edge of this end moraine rises remarkably suddenly from the level of the ground moraine to hills 30 to 50 feet high. Ground moraine covers the rest of the township. The drift, which is thin in ground moraine areas and near Threehills Creek but thicker in areas of end moraine, has an average thickness of perhaps 20 to 25 feet.

None of the wells recorded obtains water from the surficial material. The lake sediment and ground moraine are too thin and contain too much clay to provide an adequate water supply. Although water should be available from the end moraine, it will be hard in quality, variable in quantity, and the wells will require much maintenance.

The Paskapoo formation underlies the surface material and is the common source of water. However, several wells that tap lower aquifers may enter the Edmonton formation, which is everywhere a potential source of soft water for deep drilling. All the wells recorded are drilled, are from 32 to 200 feet deep with an average depth of about 90 feet, and tap aquifers between 2,765 and 2,950 feet above sea-level. Most aquifers between 2,765 and 2,865 feet yield good quantities of soft water without noticeable iron, whereas most between 2,875 and 2,950 feet supply fair to good quantities of hard water, usually with a considerable amount of iron but never so much as to prevent use. The water commonly has enough pressure to rise one-half to two-thirds of the distance to the surface.

In general, the bedrock yields ample water for ordinary farm use at comparatively shallow depth anywhere in the township, and larger quantities are probably available.

Township 34, Range 26. The west part of the township is marked by a hilly, uneven ridge of bedrock that forms the divide between Kneehills and Threehills Creeks and rises 300 to 400 feet above them. Kneehills Creek crosses the southwest corner and Three-hills Creek the northeast. The surface of the township is mainly rough and hilly, with the major, bedrock features modified by lesser, drift features.

Rolling knob and kettle end moraine, with knolls as much as 20 to 30 feet high, covers about 20 square miles, chiefly in the higher districts of the centre and southeast. A flat mantle of lake clay covers about 2 square miles in the southwest and northeast, and the remaining area, mostly on the gentle valley walls of the creeks, has a cover of ground moraine. The drift, which is thickest in end moraine areas, probably averages 15 to 20 feet in thickness.

The only well recorded that draws water from the surface material obtains an adequate supply of hard water from end moraine.

Although water could be obtained elsewhere in the end moraine, wells into it would not be as satisfactory as wells into bedrock. Any attempt to obtain water from the ground moraine or lake clay is inadvisable as they are thin and contain much clay.

The Paskapoo formation directly underlies the surficial material. The Edmonton formation is 300 to 500 feet below the surface and is too deep to affect either the topography or the water supply. Two wells dug into bedrock obtain sufficient hard water with much iron. All other bedrock wells are drilled to depths of from 33 to 210 feet, with an average depth of 85 feet. They tap aquifers between 2,895 and 3,190 feet above sea-level, but mostly in the zones 2,985 to 3,005, 3,075 to 3,120, and 3,150 to 3,190 feet. About half the wells yield hard water, the others moderately hard or soft water, and one-quarter supply water that contains noticeable iron, although rarely so much as to prevent its use. The quantity of water is generally fair to good, and the one well with insufficient water, although deep, is drilled on a hillside that drops below the elevation of the well bottom. Its supply would be improved with deepening. The water commonly has enough pressure to rise half the distance to the surface.

In general, ample water is available anywhere in the bed-rock at a smaller average depth than in surrounding townships, and large supplies, as for town use, should be obtainable.

Township 34, Range 27. Kneehills Creek flows southward near the east border of the township through a broad valley 150 feet deep, and is joined by another valley that drains Davey Lake near the centre of the township. A dry valley, 200 feet deep and a mile wide, crosses the southwest corner. The surface is rolling, and large, commonly isolated, drift hills, 20 to over 50 feet high, cover 5 square miles south of Davey Lake and have indeed blocked a valley to form the lake.

Except for some 3 square miles of the valley of Kneehills Creek that is covered by a relatively flat mantle of lake silt and clay, the rest of the area is underlain by ground moraine that is never thick enough to obscure the bedrock topography. As the average thickness of drift probably is not more than 15 feet, and as it contains much clay, any attempt to find water in it is inadvisable, although some may be available in the end moraine.

The Paskapoo formation underlies the drift, and all wells enter it. Five are dug to an average depth of 25 feet and yield good supplies of hard water. All the other wells examined are drilled and are 34 to 204 feet deep, with an average depth of 100 feet. They tap aquifers between 2,870 and 3,220 feet above sea level, but most draw from a zone between 3,060 and 3,160 feet. The higher aquifers are used in the west. All yield a fair to good quantity of water, which in half the wells, particularly in those tapping the lower aquifers, is soft without noticeable amounts of iron. With some exceptions, the water is under enough pressure to raise it more than half-way to the surface.

In general, sufficient good water for ordinary farm needs or even for uses requiring large quantities is present at relatively shallow depth in the bedrock everywhere in this township.

Township 34, Ranges 28 and 29. The surface of these townships, which characteristically is gently rolling, rises towards the south. The chief topographic features are two southeast trending dry valleys 100 to 200 feet deep and about 1 mile wide, one in the east and the other in the centre of the area.

Alluvial sand overlies bedrock in the valleys, but the rest of the area has a mantle of rolling ground moraine, which here and there becomes as hilly as low end moraine. Chiefly because the average thickness of drift is probably no greater than 10 or 15 feet, no wells obtain water from it, and any attempt to do so is inadvisable.

The Paskapoo formation, which directly underlies the drift, supplies all the water used, and the drilled wells into it are 12 to 280 feet deep, with an average depth of about 90 feet. They tap aquifers between 2,830 and 3,260 feet above sea-level, and particularly from the zones 3,055 to 3,085, 3,110 to 3,120, and 3,150 to 3,215 feet. Sixty per cent of the wells yield soft water, and although that from low aquifers is generally softest, many of these low aquifers do not yield as much water as higher ones. The amount of iron is negligible, and the water has generally enough pressure to rise about half the distance from the aquifer to the surface.

These townships, like those to the south, are interesting for the large number, 24 in this instance, of rather similar wells dug into bedrock. These wells have an average depth of 27 feet and tap aquifers between 3,065 and 3,275 feet above sea-level, but chiefly from 3,175 to 3,255 feet. Most of them yield hard water, some with noticeable iron, in fair to good quantity. These wells generally are adequate for ordinary farm use, but the supply in several is insufficient during dry years.

In general, adequate water for normal needs is available in the bedrock at comparatively shallow depth anywhere in these townships, and large amounts can be obtained.

ANALYSES OF WELL WATERS FROM Townships 31-34, Ranges 25-29, West 4th Meridian, Alberta

Sample Number	¼	Section	Township	Range	Meridian	Owner	Depth of well (feet)	Aquifer *	Total dissolved solids (parts per million)	Constituents as Analysed (parts per million) Calcium (Ca)	Magnesium (mg)	Alkalis (Na,K)	Sulphate (SO4)	Chloride (Cl)	Nitrate (NO_3)	Bicarbonate (HCO_3)	Alkalinity (as $CaCO_3$)	Hardness as ($CaCO_3$) (pts. per million) Ca hardness	Mg hardness	Total hardness
3768	NE	2	31	29	4	A. Synder	200	P	1374	6.8	5.2	465.5	607.0	1.4	1.8	525.8	437.0	17.0	21.4	38.4
3769	SW	24	31	29	4	W. Ausenhus	175	P	1254	12.1	52.2	356.7	674.1	2.8	Nil	267.7	261.5	30.2	214.8	245.0
3770	SE	20	31	28	4	J.E. McNeill	35	P	1420	8.4	5.0	481.2	547.3	1.4	1.8	542.9	451.0	21.0	20.6	41.6
3771	NW	8	31	28	4	A. Morasch	85	P	1032	11.2	6.3	385.9	361.7	2.1	1.6	545.8	447.4	27.9	25.9	53.8
3772	NW	22	31	27	4	H. Thomson	109	P	1482	78.5	32.5	441.0	489.7	7.1	Nil	849.1	696.0	195.9	132.9	328.8
3773	NW	30	31	27	4	S.R. McAllister	120	P	1066	38.0	20.1	355.4	290.1	7.8	6.2	706.4	579.0	94.8	82.7	177.5
3782	SW	14	31	27	4	R. Jenkins	100	P	918	49.2	18.6	299.1	103.3	1.2	Nil	832.0	682.0	122.8	76.5	199.3
3783	NE	32	31	26	4	J. Raffan	60	P	2130	218.8	133.5	198.2	1162.2	1.8	40.0	303.0	248.6	545.9	549.4	1095.3
3784	SE	28	31	26	4	J. Fleming	96	P	1140	167.3	65.6	117.7	434.6	Nil	Nil	577.3	473.2	417.4	269.9	687.3
3785	SW	6	32	25	4	G. Schafer	58	P	684	12.2	5.7	261.1	156.0	1.5	8.0	496.5	407.0	30.4	23.5	53.9
3786	NW	24	32	29	4	S.M. McDonald	188	P	1472	46.6	22.9	488.5	632.9	Nil	Nil	626.3	513.4	116.3	94.2	210.5
3920	NW	31	32	28	4	L.C. Hammer	85	P	752	36.0	13.6	238.5	155.6	Nil	10.6	586.6	480.8	89.8	56.0	145.8
3921	NE	17	32	28	4	A. Zimmerman	140	P	894	13.0	5.6	355.0	101.6	60.4	Nil	723.7	593.2	32.4	23.0	55.4
3922	NW	29	32	27	4	F.J. Grapentine	262	P	712	55.8	19.1	189.5	142.4	Nil	6.2	567.3	465.0	139.2	78.6	217.8
3923	NW	28	32	27	4	H. Walshlager	73	P	686	39.9	12.8	200.0	127.2	Nil	6.2	567.3	465.0	99.6	52.7	152.3
3924	NW	6	32	26	4	N. McCullough	250	P	1900	12.3	3.5	647.2	933.4	19.6	0.7	539.2	450.0	30.7	14.4	45.1
3953	SE	2	33	26	4	E.M. Enzie	80	P	1426	57.0	19.0	433.5	475.3	13.7	3.5	793.0	650.0	142.2	78.2	220.4
3954	SW	19	33	26	4	G.L. Kline	130	P	1160	4.5	1.3	431.0	314.4	Nil	2.7	731.0	630.4	11.2	5.3	16.5
3955	SW	7	33	25	4	A. Schlichenmayer	5	P	1836	39.3	58.8	500.5	947.3	Nil	1.8	479.0	417.4	98.1	242.0	340.1
3956	SW	10	33	24	4	W.H. Kinsey	85	P	2636	203.2	117.5	511.5	1282.7	7.7	31.9	833.7	683.4	507.0	483.5	990.5
4183	NW	30	34	25	4	H. Howard	56	P	1960	64.0	45.0	554.2	903.3	Nil	TRACE	718.5	584.0	159.7	185.2	344.9
4184	NE	5	34	25	4	J. Veres	117	P	1910	99.5	116.7	384.6	845.7	Nil	TRACE	806.4	661.0	248.3	480.2	728.5

* Symbols used for aquifers; P - Paskapoo Formation.

CANADA

DEPARTMENT OF MINES

AND

TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

WATER SUPPLY PAPER No. 315

GROUND-WATER RESOURCES OF TOWNSHIPS 11 to 14, RANGES 22 to 25, WEST OF PRINCIPAL MERIDIAN, MANITOBA

(Hamiota Area)

By

E. C. Halstead

OTTAWA

1953

NOTE:

Because of difficulties involved in reproduction, the tables of well records referred to are not included with this report. Information regarding individual wells may be obtained by writing to the Director, Geological Survey of Canada, Ottawa.

C A N A D A
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PART I

INTRODUCTION

The present report is an attempt to assemble the data on ground-water resources in a form that will be useful to well drillers, farmers, municipal authorities, and others interested in obtaining adequate water supplies.

Publication of Results

The essential information pertaining to ground-water conditions is being issued in reports that, in Manitoba, cover a square block of sixteen townships lying between the correction lines and beginning at the Saskatchewan boundary. The reports on the most southerly strip of the province include in addition the two townships lying north of the International Boundary. The secretary-treasurer of each municipality will be supplied with the information covering that municipality, and copies of the reports will also be available for study at offices of the Provincial and Federal Departments. Further assistance in interpreting the reports may be obtained by applying to the Chief Geologist, Geological Survey of Canada, Ottawa.

How to Use the Report

Anyone desiring information concerning ground-water in any particular locality will find the available data listed in the well records, and other pertinent information on the maps of the area. For those unfamiliar with these reports it is, perhaps, advisable that that part dealing with the area as a whole be read first, so as to be in a better position to understand the more particular descriptions of each township that follow. Also, the map accompanying the report should prove a useful source of reference when reading the text.

The map consists of two figures. Figure I shows bedrock and surface geology. The water-bearing properties of the bedrock change from formation to formation, and are referred to in subsequent pages. The type of glacial deposit at the surface may be determined from the map, and its possibilities as an aquifer are also discussed in this report.

Figure 2 shows the location and types of wells in the area, the land relief (topography), and the drainage pattern. Not every well is plotted on the map, but most of those giving pertinent information are shown, and probably include 90 per cent of the wells in the area. Where ground water is not readily available, or carries too much dissolved salts to be used, dugouts often form the only means of supply. The topography is shown by contours, or lines of equal elevation, spaced at vertical intervals of 50 feet.

The well records are compiled from data obtained by interviewing farmers, and in many cases their accuracy depends upon the farmer's memory. Wherever possible data were checked by plumb-line measurement to the nearest foot. The wells are tabulated by townships and sections, and the total depth of the well, depths to the water level at high and low stages, and, where possible, the depth at which the water-bearing horizon occurs, are all listed. The general character of the water is stated, and the use to which it can be put. Wells from which samples were taken for analysis are indicated on the well-record sheets. An idea of how much water a well can be expected to yield is suggested by the number of stock (cattle and horses only) that can be watered at it. One head is assumed to consume between 8 and 10 gallons of water a day. Unless followed ~~by the word "only"~~

the figure for the number of stock watered is not necessarily the maximum yield of the well, but simply the greatest amount that the present user has required. The word "only" indicates that the figure given is the maximum yield of the well. To obtain the position of an aquifer at any given point, the elevation of the point should be determined from the contours on Figure 2 of the map. Elevations of adjacent wells may be found in the well records and the depth to the aquifer can usually be determined from them. By comparing elevations the depth of the aquifer below the unknown point may be estimated. This method is particularly applicable to bedrock wells, but may not be successful where information is too limited, or where the glacial drift is thick and of an irregular character. In such instances a person searching for water should refer to the text for information on the nature of the deposits in that area.

GLOSSARY OF TERMS USED

Alkaline. The term 'alkaline' or 'alkali' water has been applied rather loosely to waters having a peculiar and disagreeable taste, and commonly a laxative effect. The waters so described in the Prairie Provinces are those heavily charged with sulphates of magnesium and sodium (respectively Epsom salts and Glauber's salts) and are more correctly termed sulphate waters. Truly 'alkaline' waters owe that property to the presence of calcium carbonate and calcium bicarbonate. In this report an attempt to adhere to local terminology is made by referring to sulphate waters as 'alkali' in the well records, and the term 'alkaline' is avoided.

Alluvium. Deposits of clay, silt, sand, gravel, and other material in lake beds and in flood plains of modern streams. The term also includes the material in river terraces, which once formed part of the flood plain but are now above it.

Aquifer. A porous bed, lens, pocket, or deposit of material that transmits water in sufficient quantity to satisfy pumping wells and springs.

Bedrock. Bedrock, as here used, refers to partly or wholly consolidated deposits of gravel, sand, silt, clay, and marl that are older than the glacial drift.

Bentonite and bentonitic clays have the property of swelling when water is added to them. They occur as white beds as much as 2 feet thick, but usually much thinner, and are probably formed by the weathering of volcanic ash.

Buried pre-Glacial Stream Channel. A channel eroded into the surface of the bedrock by a stream before the advance of the continental ice-sheet, and subsequently either partly or wholly filled in by sands, gravels, and boulder clay deposited by the ice-sheet or later agencies.

Coal Seam. The same as a coal bed. It is a deposit of carbonaceous material formed from the remains of plants by partial decomposition and burial.

Contour. A line on a map joining points that have the same elevation above sea-level.

Continental Ice-sheet. The great ice-sheet that covered most of the surface of Canada many thousands of years ago.

Escarpment. A cliff or relatively steep slope separating level or gently sloping areas.

Flood Plain. A flat part of a river valley ordinarily above water but submerged when the river is in flood. It is an area where silt and clay are being deposited.

Glacial Drift. A general term that includes all the loose, unconsolidated materials that were deposited by the ice-sheet, or by the waters associated with it. Clay containing boulders usually forms a large part of the glacial drift in an area, and is called glacial till or boulder clay, and is not to be confused with the more general term glacial drift, which occurs in the following several forms:

(1) Terminal Moraine or Moraine. A ridge or series of ridges formed by glacial drift that was laid down at the margin of a moving ice-sheet. The surface is characterized by irregular hills and undrained basins.

(2) Kame Moraine. Assorted deposits of sand and gravel laid down at or close to the ice margin. The topography is similar to that of a terminal moraine.

(3) Ground Moraine. Boulder clay (till) laid down at the base of an ice-sheet. The topography may vary from flat to gently rolling.

(4) Glacial Outwash. Sand and gravel plains or deltas formed by streams that issued from the continental ice-sheet.

(5) Glacial-lake Deposits. Sand, silt, and clay deposited in glacial lakes during the retreat of the ice-sheet.

Shoreline. A discontinuous escarpment, with intervening gravel beaches and bars, which indicates the former margin of a glacial lake.

Ground Water. The water in the zone of saturation below the water-table.

Hydrostatic Pressure. The pressure that causes water in a well to rise above the point at which it was first encountered in the well, namely, at the level of the aquifer.

Impervious or impermeable. Beds such as fine clays or shale are considered to be impermeable when they do not permit the perceptible passage or movement of ground water.

Pervious or Permeable. Beds are pervious or permeable when they permit the perceptible passage or movement of ground water, as in the case of sands and gravels.

Pre-Glacial Land Surface. The surface of the land as it existed before the ice-sheet covered it with drift.

Recent Deposits. Deposits that have been laid down by the agencies of water and wind since the disappearance of the continental ice-sheet; for example, alluvium in stream valleys.

Sand Point or Driven Well. A sand point is a piece of perforated and screened pipe 2 or 3 feet long, which ends in a sharp point. It is fastened to lengths of ordinary pipe and forced down into surface deposits of a sandy or gravelly nature. The depth of such a well rarely exceeds 30 feet.

Unconsolidated Deposits. The mantle or covering of alluvium, pre-glacial soils, and glacial drift consisting of loose, uncemented material that overlies the bedrock.

Variegated. Beds so described show different colours in alternating beds or lenses.

Water-table. The upper limit of the part of the ground saturated with water. This may be near the surface or many feet below it. A water-table is said to be perched when a zone of saturated material is separated from the main water-table below by a zone or zones of unsaturated material.

Water-worked Till. Glacial till or boulder clay that has been subjected to water action, usually near the margins of glacial lakes, so that the fine clay has been washed out and a deposit that may be composed mainly of sand and gravel is left behind.

Wells. The term refers to any hole sunk in the ground by any means for the purpose of obtaining water. If no water is obtained they are referred to as dry holes. Wells yielding water are divided into four classes:

(1) Flowing Artesian Wells. Wells in which the water is under sufficient hydrostatic pressure to flow above the surface of the ground at the well.

(2) Non-flowing Artesian (Sub-artesian) Wells. Wells in which the water is under sufficient hydrostatic pressure to raise it above the level of the aquifer, but not above the level of the ground at the well.

(3) Non-artesian Wells. Wells in which the water does not rise above the water-table or the aquifer.

(4) Intermittent Non-artesian Wells. Wells that are generally dry for a part of each year.

GENERAL DISCUSSION OF GROUND WATER

Almost all the water recovered from beneath the earth's surface for both domestic and industrial uses is meteoric water, that is, water derived from the atmosphere. Most of this water reaches the surface as rain or snow. Part of it is carried off by streams as run-off; part evaporates either directly from the surface and from the upper mantle of soil, or indirectly through transpiration of plants; and the remainder sinks into the ground to be added to the ground-water supplies.

The proportion of the total precipitation that sinks into the ground will depend largely upon the type of soil or surface rock, and on the topography; more water will sink into sand and gravel, for example, than into clay; if, on the other hand, the region is hilly and dissected by numerous streams, more water will be immediately drained from the surface than in a relatively flat area. Light, continued precipitation will furnish more water to the underground supply than brief torrential floods, during which the run-off may be nearly equal to the precipitation. Moisture failing on frozen ground will not usually find its way below the surface, and, therefore, will not materially replenish the ground-water supplies. Light rains falling during the growing season may be wholly absorbed by plants. The quantity of moisture lost through direct evaporation depends largely upon temperature, wind, and humidity. Locally these deposits may become very extensive. The water-bearing properties of alluvial deposits are variable, but, in general, such deposits form favourable aquifers. They are porous, and readily yield a part of their contained water, although in places their porosity may be greatly reduced by the presence of fine silt and clay. This type of deposit may be expected to yield moderate domestic supplies through shallow wells, and larger supplies if ~~the deposits are extensive~~.

In some areas of relatively steep slopes, valleys have been partly filled with sand and gravel, which, in turn, have been covered with impervious clay and silt. These circumstances commonly give rise to artesian conditions in the lower part of the valley.

DISCUSSION OF WATER ANALYSES

Both the kind and quantity of mineral matter dissolved in a natural water depend upon the texture and chemical composition of the rocks with which the water has been in contact. Pollution is caused by contact with organic matter or its decomposition products. Analyses of well waters for mineral content are made by the Department of Health and Public Welfare, Winnipeg, and by the Bureau of Mines, Department of Mines and Resources, Ottawa.

As the ground-water survey of Manitoba progresses an effort is made to secure samples representative of each major aquifer encountered; the purpose of this is to compare the chemical characteristics of waters from the various geological horizons and, thereby, assist in making correlations of the strata in which the waters occur. The mineral content of natural waters is also of interest to the consumers, though the effects of the constituents are usually already apparent. The quantities of the various constituents for which tests are made are given as 'parts per million', which refers to the proportion by weight of each constituent in 1,000,000 parts of water. A salt when dissolved in water separates into two chemical units called 'radicals', and these are expressed as such in the chemical analyses. In one group are included the metallic elements of calcium (Ca), magnesium (Mg), sodium (Na), and iron (Fe), and in the other group are the sulphate (SO_4), chloride (Cl), bicarbonate (HCO_3), carbonate (CO_3), and nitrate (NO_3) radicals. The radicals listed in the analyses tabulated in the second part of this report can be combined to give the actual quantity of the particular salts present in the water, but this is not done here as the radicals alone give enough information to identify the water types. In fact, the sulphate, chloride, and carbonate radicals, plus the hardness, serve to identify a water, and crude field tests on the basis of these constituents were used in some areas to outline more completely zones of the various water types.

The following mineral constituents include all that are commonly found in natural waters in quantities sufficient to have any practical effect on the value of waters for ordinary uses:

Silica (SiO_2) is dissolved in small quantities from almost all rocks. It is not objectionable except in so far as it contributes to the formation of boiler scale.

Iron (Fe) in combination is dissolved from many rocks as well as from iron sulphide deposits with which the water comes in contact. It may also be dissolved from well casings, water pipes, and other fixtures in quantities large enough to be objectionable, but separates as the hydrated oxide upon exposure of the water to the atmosphere. Excessive iron in water causes straining on porcelain or enamelled ware, and renders the water unsuitable for laundry purposes. Water is usually considered not potable if the iron content is more than 0.5 part per million.

Calcium (Ca) in the water comes from mineral particles present in the surface deposits, the chief sources being limestone, gypsum, and dolomite. Fossil shells provide a source of calcium, as does also the decomposition of igneous rocks. The common compounds of calcium are calcium carbonate ($CaCO_3$) and calcium sulphate ($CaSO_4$), neither of which have injurious effects on the consumer, but both of which cause hardness.

Magnesium(Mg) is a common constituent of many igneous rocks and, therefore, very prevalent in ground water. Dolomite, a carbonate of calcium and magnesium, is also a source of the element. The sulphate of

magnesia ($MgSO_4$) combines with water to form 'Epsom salts,' and renders the water unwholesome if present in large amounts.

Sodium(Na) is derived from a number of the important rock-forming minerals, so that sodium sulphate and carbonate are very common in ground waters. Sodium sulphate (Na_2SO_4) combines with water to form 'Glauber's salt' and excessive amounts make the water unsuitable for drinking purposes. Sodium carbonate (Na_2CO_3) or 'black alkali' waters are mostly soft, the degree of softness depending upon the ratio of sodium carbonate to the calcium and magnesium salts. Waters containing sodium carbonate in excess of 200 parts per million are unsuitable for irrigation purposes[1]. Sodium sulphate is less harmful.

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[1] "The extreme limit of salts for irrigation is taken to be 70 parts per 100,000, but plants will not tolerate more than 10 to 20 parts per 100,000 of black alkali (alkaline carbonates and bicarbonates)". Frank Dixey, in 'A Practical Handbook of Water Supply', Thos. Murby & Co., 1931, p. 254.

Sulphates (SO_4) referred to in this report are those of calcium, magnesium, and sodium, and have been mentioned above in referring to these radicals. They are also formed by oxidation of iron sulphides, and, hence, it is not uncommon to find iron in sulphate waters. Sulphates cause permanent hardness in water, and injurious boiler scale. Sodium and magnesium sulphates are laxative when present in quantities of more than 900 parts per million. The writers found that acclimatized people could drink water containing as much as 2,000 parts per million of all three of the principal sulphates, but that when all were present in quantities over 1,500 parts per million the water was commonly laxative to those not accustomed to it.

Chloride (Cl) is a constituent of all natural waters and is dissolved in small quantities from rocks. Waters from wells that penetrate brines or salt deposits contain large quantities of chloride, usually as sodium chloride (common salt) and less commonly as calcium chloride and magnesium chloride. Sodium chloride is a characteristic constituent of sewage, and any locally abnormal quantity suggests pollution from this source. However, such abnormal quantities should not, in themselves, be taken as positive proof of pollution in view of the many sources from which chloride may be derived. Chlorides impart a salty taste to water if present much in excess of 500 parts per million. In southwestern Manitoba waters with as much as 3,000 parts per million of chloride are used domestically, though more than 1,500 parts per million is generally considered undesirable. The following figures apply to chlorides: stock will require less salt if the water bears 2,000 parts per million; more than 5,000 parts per million is unfit for human consumption; more than 8,000 parts per million is unfit for horses; more than 9,500 parts per million is too much for cattle; and more than 15,500 parts per million is excessive for sheep. Magnesium chloride, less common than sodium chloride, is very corrosive to metal plumbing.

Nitrates (NO_3) found in ground water are decomposition products of organic materials; they are not harmful in themselves, but they do point to probable pollution. It is recommended that a bacterial test be made on water showing an appreciable nitrate content, if it is to be used for domestic purposes.

Carbonates (CO_3) in water are indicated in the table of analyses as 'alkalinity'. Calcium and magnesium carbonate cause hardness in water, which may be partly removed by boiling. Sodium carbonate causes softness in waters, and is referred to under 'Sodium' above.

Bicarbonates (HCO_3). Carbon dioxide dissolved in water renders the insoluble calcium and magnesium carbonates soluble as bicarbonates. The latter are decomposed by boiling the water, which changes them to insoluble carbonates.

Hardness is a condition imparted to waters chiefly by dissolved calcium and magnesium compounds. It here refers to the soap-destroying power of water, that is, to the amount of soap that must first be used to precipitate the above compounds before a lather is produced. The hardness of water in its original state is its total hardness, and is classified as 'permanent hardness' and 'temporary hardness'. Permanent hardness remains after the water has been boiled. It is caused by mineral salts that cannot be removed from solution by boiling, but it can be reduced by treating the water with natural softeners, such as ammonia or sodium carbonate, or with many manufactured softeners. Temporary hardness can be eliminated by boiling, and is due to the presence of bicarbonates of calcium and magnesium. Waters containing large quantities of sodium carbonate and small amounts of calcium and magnesium compounds are soft, but if the latter compounds are present in large quantities the water is hard. The following table[1] may be used to indicate the degree of hardness of a water:

Total Hardness

Parts per million	Character
0-50	Very soft
50-100	Moderately soft
100-150	Slightly hard
150-200	Moderately hard
200-300	Hard
300 +	Very hard

The above table gives the generally accepted figures for hardness, but the people of southwestern Manitoba have become accustomed to harder waters, and the following table, based on about 800 field determinations of hardness, by the soap method, is more applicable:

Parts per million	Character
0-100	Very soft
100-150	Soft
150-250	Moderately hard
250-350	Hard
350-500	Very hard
500+	Excessively hard

Waters having a hardness of up to 300 parts per million are commonly used for laundry purposes. In southwestern Manitoba, hardness ranges from less than 50 parts per million to more than 2,500 parts per million.

[1] Thresh, J.C., and Beale, J.F.: The Examination of Waters and Water Supplies; London, 1925, p. 21.

PART II

TOWNSHIPS 11 TO 14, RANGES 22 TO 25, WEST PRINCIPAL MERIDIAN, MANITOBA (Hamiota area)

Introduction

An investigation of the glacial geology and the ground-water resources of tps. 11 to 14, rges. 22 to 25, W. Princ. mer., was carried on by the writer during the field season of 1950.

Physical Features

The general character of the topography is that of an uneven, undulating plain with elevations ranging from 1,800 feet above sea-level in tp. 14, rge. 22, to 1,250 feet above sea-level in the Assiniboine Valley, which crosses tps. 11 and 12, rge. 25. A belt of end moraine, from 1 mile to more than 5 miles wide, crosses the area, and its long narrow hills, the Arrow Hills, rise 40 to 50 feet above the surrounding plain. Undrained depressions in this end moraine may cover 25 acres or more and are occupied by permanent lakes. The lake west of Lenore occupies a depression 3 miles long and about $\frac{1}{4}$ mile wide that has been gouged out of the bedrock.

Assiniboine River crosses the western margin of the area. Its wide floor is bordered by gullied walls that rise 150 feet or more above the river. Oak River, an intermittent stream, flows south to the Assiniboine Valley and its branching tributaries have dissected and gullied the overburden in tp. 11, rges. 22 and 23.

Geology

Table of Formations

Age	Formation	Character	Thickness (Feet)
Recent	Alluvium	Stream-laid mud, silt, sand, and gravel	
Pleistocene	Lake beds	Silty clay, fine sand and silt, duned sand, assorted sand and gravel in beaches and deltas	0-50
	Glacial drift	Till, clay, sand, gravel, boulders, assorted sand and gravel in outwash plains	0-300
Upper Cretaceous	Riding Mountain	Upper beds of medium to light grey, hard, siliceous shale (Odanah shale), with some thin layers of fine blue sand and bentonite beds; lower beds of slippery clay shale that tends to slump	1,000+
	Vermilion River	Dark grey and black shale; comprising three members; <u>Pembina</u> (dark shale, numerous bentonite bands near base); <u>Boyne</u> (grey, calcareous shale, non-calcareous dark shale near base); and <u>Morden</u> (calcareous speckled shale, overlying dark grey, non-calcareous, blocky shale with thin partings of white sand)	80± 140± 190±
	Favel	Grey shale with white calcareous material; some bands of limestone; some bentonite	150±
Lower and Upper Cretaceous	Ashville	Dark grey to black shale with silt and sand	40±
Lower Cretaceous	Swan River	White to green sandstone, black shale and silt	50±
Jurassic		Light grey to red shale, calcareous sandstone, grey to buff to brown shale, light grey limestone and sandstone	380±
Jurassic or earlier	Amaranth	Red beds and gypsum	220±

The map-area is underlain by Upper Cretaceous shale of the Riding Mountain formation. This shale outcrops along the walls of the Assiniboine Valley and on the margin of the lake west of Lenore. One water-bearing zone of the bedrock is its upper fractured and weathered surface, which yields a supply of hard, commonly alkali, watter with much iron. In the southwestern quarter of the area bedrock is overlain by an average of 20 feet of overburden.

End moraine occupies a belt in the west half of the area. It is made up of till pushed and piled by the continental ice mass, and outwash sand and gravel that was deposited by run-off streams. The outwash deposits are excellent aquifers. Ground moraine overlies the bedrock in the remainder of the area and varies in thickness from less than 15 feet in tp. 11, rge. 25, to 150 feet or more in the northeast corner. It is made up of blue, clay-rich till overlain by 20 feet or more of buff weathered till. This till is impervious and only limited supplies of water are available from discontinuous lenses or pockets of sand and gravel in it. Glacial Lake Souris covered the southern half of this block. In it silt and sand were deposited and wave action winnowed out the finer materials and modified the ground moraine. The lake bed deposits are too thin to be valuable as aquifers.

Water Supply

Water supply has been no problem in the north half of this area. Wells are dug into outwash gravel in the area of end moraine, and elsewhere a supply is obtained from wells drilled below the blue clay to layers of fine sand and gravel or to the upper fractured surface of the bedrock. The water is commonly alkali, but can be used for the household as well as for stock, although the concentration of iron that precipitates as the red iron hydroxide makes the water unsatisfactory for domestic use. The water may be filtered through a simple home-made filter of sand and charcoal.

South of Harding the search for water has been costly and

many farms depend entirely upon dugouts. The impervious till lacks lenses of gravel or sand and the water that slowly entered the test holes contains enough alkali salts to be unfit for use. The shallow patches of outwash gravel along abandoned stream channels are the only source of potable water. Such aquifers as these are apt to fail in years of drought and to freeze in winter months.

Township 11, Range 22. Assiniboine River crosses sections 1 and 2. North of the river a broad valley floor, about 3 miles wide, is covered with lake-bed sand except for a long oval hill of outwash gravel about 5 miles long and in places more than a mile wide. This is an excellent aquifer and wells dug into it to depths of 20 to 30 feet yield an abundant supply of hard clear water.

North of the broad valley the surface is dissected by Oak River and its three branching tributaries. Many of the gullies and channels so formed have cut 100 feet or more into glacial till, the surface of which has been reworked by waters of glacial Lake Souris. Wells are dug 15 to 30 feet deep to discontinuous lenses of sand or gravel in the glacial till, or in patches of outwash or windblown sand. The supply is commonly sufficient. In sections 19, 20, 21, 29, and 30 the wells are dug from 60 to 72 feet deep, to a layer of black sand that yields hard, clear water having much iron. A well tapping this aquifer will yield enough water for 100 head or more. In NW.$\frac{1}{4}$ section 25, a well 114 feet deep reached a layer of fine sand that filled it in to a depth of 98 feet. It is now dry.

Township 11, Range 23. Impervious blue clay of the ground moraine underlies the silts deposited on the surface by waters of glacial Lake Souris. The branching tributaries of Oak River have dissected the township leaving a rolling channelled surface conducive to rapid runoff. In consequence there is little replenishment of the ground water reservoir and supply of ground water is inadequate, so that dugouts are necessary for a stock supply. Everywhere wells have

been dug, bored, or drilled to a depth of 50 to 120 feet only to prove dry or to obtain water that was too alkali for stock. Black alkali water, with a high concentration of sodium carbonate, is common in the test holes dug in the south part of the township.

In SE.¼ section 29, a well bored 85 feet reaches a layer of fine sand below blue clay. Its water is alkali and contains much iron, but has been a constant supply for 15 to 20 head of stock. In SW.¼ section 35 a well dug 74 feet to a layer of gravel now supplies 25 head of stock, but, during the years of drought, would supply only 4 head of horses. On the same quarter section another well drilled 150 feet deep reaches a layer of fine sand and yields only a barrel of water a day. Shallow dug wells along the creeks are commonly a source of drinking water.

Township 11, Range 24. Arrow Hills, with a width of 1 mile to 4 miles, are formed in a belt of end moraine trending south across the township. Their elongate hills and undrained depressions are made up of glacial till and outwash gravel. The overburden is only 10 to 24 feet thick, as bedrock is encountered in wells between these depths. That part of the end moraine not included in the Arrow Hills was modified by waters of glacial Lake Souris and it and the ground moraine are covered by a thin layer of lacustrine silt.

A supply of good water is available in the sand and gravel of the end moraine. Elsewhere wells are dug through ground moraine to bedrock, where sufficient supplies are obtained at an average depth of 30 feet. In NE.¼ section 4, a layer of sand in blue clay at 97 feet, yields soft, clear water, but in section 6, no water, other than black alkali water, was encountered in any test holes.

Township 11, Range 25. Assiniboine River crosses the township from section 31 to section 4 and meanders over a broad valley floor that is, in places, about a mile wide. The walls of the valley, 200 feet high, are gullied and dissected by short streams. Beyond the valley the uneven to flat surface is formed on ground moraine

modified by waters of glacial Lake Souris. Bedrock is 10 to 30 feet from the surface and wells dug to it yield a supply of hard, clear water. Wells may be deepened if the supply should fail during seasons of drought. A sufficient supply of water is found everywhere in this township.

Township 12, Range 22. Oak River enters this township in section 36 and leaves in section 6. It and its abandoned channels dissect the otherwise gently rolling surface. An intermittent tributary of Oak River also crosses sections 12, 1, and 2. The overburden consists of ground moraine much of which has been modified by wave action of waters of glacial Lake Souris. Patches and low ridges of sand and gravel are also present, many of which were deposited along the abandoned channels of Oak River and along the shores of the glacial lake as its level dropped.

Patches of outwash sand and gravel are the chief but very localized aquifers in the township. The village of Bradwardine, for instance, is on an outwash plain and has an abundant supply of good water from shallow wells. Elsewhere wells are dug 30 to 50 feet into the blue clay but yield a supply of water that is commonly not sufficient and dugouts are needed. There are however exceptions, and in SE.$\frac{1}{4}$ section 33, a well drilled 180 feet, supplies hard, iron-bearing water that is under sufficient pressure to rise to the surface and overflow.

Township 12, Range 23. This township is covered by ground moraine whose surface is uneven to undulating with undrained depressions and wooded areas. The southern half has been modified by waters of glacial Lake Souris. Dug wells are 25 to 60 feet deep through blue clay to lenses of sand and gravel. The supply is commonly sufficient for domestic uses and dugouts are built for a stock supply. Several wells, 12 to 60 feet deep, were dug on the NW.$\frac{1}{4}$ section 11, and in each

the water was too alkali to use. At Harding, five dug wells average 40 feet in depth and yield alkali water.

One of the first wells drilled was in SW.$\frac{1}{4}$ section 27, to a depth of 150 feet. Water was first encountered at a depth of 25 feet in a layer of gravel 10 feet thick, but drilling continued and a second water-bearing zone of gravel was met at 70 feet. The well was finished at a depth of 150 feet. Water of good quality rose to a distance of 35 feet from the surface. In NW.$\frac{1}{4}$ section 30 and SW.$\frac{1}{4}$ section 32, wells drilled 90 and 103 feet, respectively, reached shale at 88 feet, and water of good quality, but containing much iron, rises within 5 feet of the surface. Wells 70 to 85 feet deep are drilled in SW.$\frac{1}{4}$ and SE.$\frac{1}{4}$ section 19 and SW.$\frac{1}{4}$ section 22. These wells penetrate blue clay to seams of sand and yield alkali water for stock use only. Dry holes 115 to 118 feet deep were drilled in NE.$\frac{1}{4}$ section 22.

<u>Township 12, Range 24.</u> The surface of this township is irregular with many knolls and hills in the area of end moraine that covers all but the eastern margin of the township. Undrained depressions of considerable size are occupied by permanent lakes, Bars Lake, in sections 20 and 29, being the largest.

Wells are dug 25 to 30 feet deep through overburden to bedrock, which is 10 to 40 feet below the surface. They yield an adequate supply of soft water, which even during years of drought is sufficient for 20 head of stock. A well 120 feet deep in NW.$\frac{1}{4}$ section 12 penetrated 90 feet of blue clay and reached a layer of gravel that yields alkali water suitable for stock only. In NW.$\frac{1}{4}$ section 25 and SW.$\frac{1}{4}$ section 36 wells reached bedrock at 40 feet, and were drilled into it to a water-bearing zone at a depth of 98 feet. The water in both wells is suitable for any use.

<u>Township 12, Range 25.</u> The surface of the township slopes

to the valley of Assiniboine River, which crosses the western margin. The walls of the valley are, however, gullied by short streams. In sections 1, 2, and 11 a permanent lake occupies an elongate depression in the bedrock. Ground moraine underlies the entire township, covered in places by a thin layer of fine sand or patches of outwash sand and gravel.

Wells are dug 20 to 25 feet deep to bedrock where an adequate supply of water is obtained, either at its fractured surface or in the bedrock itself. Other wells less than 10 feet deep obtain water from the surface sands. These shallow wells are commonly dry in winter when the aquifers freeze. In NW.$\frac{1}{4}$ section 12, three wells are dug 20, 26, and 40 feet deep respectively, and all reach shale at 15 feet. During the years of drought these wells were dry until they again reached the water-table on being deepened 6 or 8 feet.

Township 13, Range 22. Ground moraine covers the entire township. Its surface is undulating with small depressions and clumps of scrub poplar trees except for the broad shallow valley of Oak River that runs from section 34 to section 1.

The overburden has nowhere yielded a sufficient supply of ground water. The upper 20 feet or more is a buff till, underlying which is a clay rich till. These tills are impervious, but local pockets and lenses of sand and gravel in them will yield a supply of hard, commonly alkali, water sufficient for 15 head of stock. The supply is variable and in years of less than normal rainfall these wells may be dry. The method followed is to dig a series of test holes 30 to 60 feet deep until a local aquifer is encountered and water enters the well. In places a zone of boulders at a depth of 45 feet is also a source of water.

Drilled wells are more successful and may obtain water either from fine sand below blue clay or in the upper fractured surface of the bedrock. These wells are drilled 90 to 160 feet and

yield a supply of hard water with much iron. In SE.$\frac{1}{4}$ section 5, a well drilled 135 feet into blue clay taps an aquifer in which the water is under sufficient pressure to flow, and when first drilled rose 3 feet above the surface of the ground.

Township 13, Range 23. Ground moraine with the characteristic undulating surface covers the township, wooded except where cleared for farming and with many undrained depressions. Most of the wells in this township are drilled 60 to 180 feet to layers of fine sand or gravel below blue clay or to the upper fractured surface of the bedrock. The water is under sufficient pressure to rise to an average of 25 feet from the surface. It is commonly alkali and contains so much iron that it is necessary to filter it for domestic use. Some wells are, however, dug 35 to 50 feet to local aquifers in the blue clay, and, although they do not yield as much water as the drilled wells, there is generally sufficient for 25 to 30 head of stock. At Oakner two wells supply the residents. One, dug 32 feet into clay, pumped and refreshed frequently, yields hard, clear water of good quality. The other well, at the school, is drilled 65 feet and is believed to tap the upper surface of the bedrock. The water in this well rises to within 8 feet of the surface.

Township 13, Range 24. The southwestern part of the township is composed of moraine, built into hills of till and gravel and depressions, the larger of which contain permanent lakes. The remainder of the township is covered with ground moraine whose surface is irregular and contains sloughs and numerous clumps of trees. The chief water-bearing zone of this township is the upper fractured surface of the bedrock, which yields abundant water containing much iron. Wells are drilled 60 to 150 feet to this zone. In sections 34, 35, and 36 a supply of good water is, however, obtained from a layer of sand 3 or more feet thick at a depth of approximately 70 feet below blue clay. Also, on those sections where wells have not been drilled, dug wells 20 to 50 feet deep yield a sufficient supply of

good water from local lenses of porous material in the blue clay.

Township 13, Range 25. Much of this township is covered by end moraine the rolling surface of which is marked by knolls and hills of gravel or glacial till. The larger, undrained depressions contain permanent lakes. Most of the southwestern part is, however, covered by sands of the former glacial-lake Souris. The sand and gravel of the end moraine and the sandy lake beds everywhere yield a supply of hard, clear water to wells less than 20 feet deep. These wells have yielded a sufficient supply even in years of drought. In the northeast corner of the township is ground moraine, and there water is obtained from bedrock or porous lenses in blue clay in wells 40 to 70 feet deep. In SE.$\frac{1}{4}$ section 29 a well 50 feet deep reaches the upper fractured surface of the bedrock at 40 feet and obtains soft water. Two wells drilled on SW.$\frac{1}{4}$ section 34 about 40 feet deep, however, yield alkali water.

Township 14, Range 22. The surface of this township is much wooded, with numerous sloughs, and is crossed by Oak River from section 30 to section 3. Ground moraine covers the entire township and is made up of a weathered buff-coloured till about 20 feet thick underlain by a blue clay-rich till. This material is impervious and any water obtained from it comes from contained lenses or pockets of sand or gravel. The chief water-bearing zone, lying at a depth of 65 to 150 feet under the blue clay, is more or less continuous and consists of a layer of porous material, chiefly sand and gravel. Some drilled wells reach shale and obtain water from its upper fractured surface. In SE.$\frac{1}{4}$ section 20, a 150-foot well reaches shale, and water rises 6 feet from the surface of the ground. All the water in the township has a considerable amount of iron.

Township 14, Range 23. Conditions in this township are similar to those in the township to the east, just described. An abundant supply of water is obtained everywhere from aquifers below the blue clay or in the upper fractured surface of bedrock. The

surface is uneven and is 60 feet lower in elevation in the south than in the north. Wells in the south are, consequently, dug, on the average, 60 feet to gravel or sand below the blue clay, and a supply of hard, clear water sufficient for 50 head of stock is obtained. In the north, however, wells are drilled to an average depth of 110 feet, but the water is under sufficient pressure to rise on the average 20 feet from the surface. Although the water is abundant it contains much iron. After filtering, however, through simple home made filters, most of the iron precipitate is removed. In the town of Hamiota a sufficient supply of water is obtained from wells 60 feet deep that reach a gravel aquifer at that depth.

Township 14, Range 24. An abundant supply of good water is obtained throughout this township from the overburden. Ground moraine covering the entire township, is made up of blue, clay-rich till overlain by about 20 feet of buff-coloured till. This till is impervious, but an aquifer of fine sand, grading in places to gravel or boulders, lies below the blue clay. Wells are drilled to depths of 80 to 208 feet, the deeper wells being in the north where the surface is at a higher elevation. The water is commonly alkali and contains an iron precipitate, but can be used for domestic purposes after it is filtered. The supply has proved sufficient, and even during the years of drought a well tapping this aquifer would water 50 head of stock.

Township 14, Range 25. The central and western part of this township is covered by end moraine built into hills and knolls and undrained depressions. Outwash gravel associated with the end moraine is a source of good water obtainable at shallow depths. Bedrock is, on the average, 20 feet below the surface in the low flat area covering sections 5 to 8 inclusive, where wells dug to its surface obtain a sufficient supply. In that part of the area not covered by end moraine the ground moraine is impervious, and wells are drilled to aquifers below the blue clay-rich till. These wells are drilled

to a depth of 100 to 200 feet, and commonly yield a sufficient supply of hard, alkali water with much iron. This water is used for domestic purposes and the iron can be partly removed by filtering.

Discussion of Water Analyses

The sample number shown in the first column of the Table of Analyses is for laboratory identification only.

Samples Nos. 4726 and 4728 are both representative of water from surface or outwash gravel. The water at Bradwardine school, No. 4726, has a total hardness of 640.0 ppm. of which 304.5 ppm. is non-carbonate or permanent hardness. The non-permanent hardness, 336.0 ppm., can be removed, and, although the water will still be hard, for southwestern Manitoba it is of good quality. The water sample No. 4728 has a greater concentration of the constituents analysed, partly because the aquifer is small and partly because the well is not pumped out and refreshed as is the case with the school well.

Samples Nos. 4727 and 4729 are representative of waters from aquifers in the blue clay. The deeper well has the greater concentration of constituents, as the water percolates through a greater depth of the clay permitting more sulphates and carbonates to be taken into solution. Both waters are, however, very hard. Sample No. 4731 again illustrates the concentration of the constituents as a greater depth of the blue clay is penetrated.

Samples Nos. 4732 and 4733 are taken from wells drilled to the bedrock and cased so that water from the blue clay does not enter the well. The analyses show soft water of good quality but the concentration of sulphates is sufficient to cause boiler and teakettle scale.

Sample No. 4730, also from the bedrock, is of poor quality and the nitrate concentration suggests contamination.

Record of Wells

The well records of this area follow in tabulated form. A commentary on these has been made on page 1 of this report. As a rule, the depth to the 'Principal water-bearing bed' has been taken as the depth of the well, and its elevation is given as such. This commonly applies to wells drilled in bedrock or to wells obtaining water from sub-artesian or artesian aquifers in glacial or bedrock formations. In such wells digging or drilling continues only until a good supply of water is obtained and then is stopped. In shallow surface deposits (up to 30 feet), wells are usually dug a short distance below the water-table during a dry season, and thereafter water enters and leaves the well at any point below the water-table. The figures on the height to which the water will rise in the well fluctuate, depending on the amount of rainfall during the season. The rainfall for the season in which the well data were collected exceeded that of average years, and the height of the water in the wells was, consequently, 5 to 8 feet higher than in years of normal rainfall.

ANALYSES OF WELL WATERS FROM Townships 11 to 14, Ranges 22 to 25, WPM. Manitoba

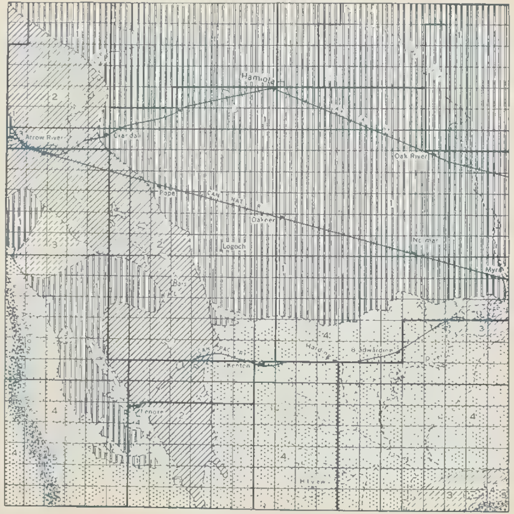
										Constituents as Analysed (parts per million)								Hardness as(CacO3) (pts. per million)		
Sample Number	¼	Section	Township	Range	Meridian	Owner	Depth of well (feet)	⌘ Aquifer	Total dissolved solids (parts per million)	Calcium (Ca)	Magnesium (Mg)	Alkalis (as Na)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Bicarbonate (HCO_3)	Alkalinity (as $CaCO_3$)	Ca hardness	Mg hardness	Total hardness
4733	NE	29	14	22	1st	J. McPhaden	69	Sh.	2152	128.0	47.0	500.0	1023.9	28.5	0	502.6	412.0	319.4	193.4	512.8
4726	SE	7	12	22	"	Bradwardine school	20	Sd.	872	180.0	46.5	33.7	318.9	10.5	0	409.9	336.0	449.1	191.4	640.5
4729	SW	35	11	23	"	S. Lowe	74	Gr.	3196	548.0	196.7	79.0	1646.1	43.5	0.7	710.0	582.0	1367.3	809.4	2176.7
4727	NE	2	12	23	"	H. Blackwell	40	Gr.	1268	265.0	61.6	35.0	417.3	50.0	10.6	597.8	490.0	661.2	253.5	914.7
4728	SE	22	12	23	"	E. Campbell	20	Gr.	3826	285.0	446.0	140.0	1991.8	78.0	78.0	690.5	566.0	711.1	1835.3	2546.4
4732	SW	35	14	23	"	Mrs. Cave	133	Sh.	2434	16.0	61.2	1080.0	1633.0	61.5	35.4	1066.3	874.0	39.9	251.8	291.7
4731	SE	17	14	24	"	M. Elliott	90	Gr.	4820	567.0	332.0	226.0	2021.4	137.5	510.0	534.4	438.0	1414.7	1366.2	2780.9
4730	SW	34	13	25	"	A. Rudd	40	Sh.	7154	500.0	597.0	640.0	3100.1	282.5	1239.6	819.8	672.0	1247.5	2456.7	3704.2

⌘ Symbols used for aquifers Sh. - Shale, Sd. - Sand, Gr. - Gravel.

CANADA
DEPARTMENT
OF
MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

FIGURE 1
MAP SHOWING TYPES OVERBURDEN



LEGEND

OVERBURDEN

CENOZOIC

QUATERNARY

RECENT

5 — ALLUVIUM
Clay, silt, sand and gravel

PLEISTOCENE

4 — WATER-WORKED TILL AND LAKE BEDS
Silt, sand and gravel

3 — OUTWASH
Sand and gravel

2 — END MORAINE
Till, sand and gravel, surface rolling and irregular

1 — GROUND MORAINE
Till with lenses of sand and gravel, surface uneven

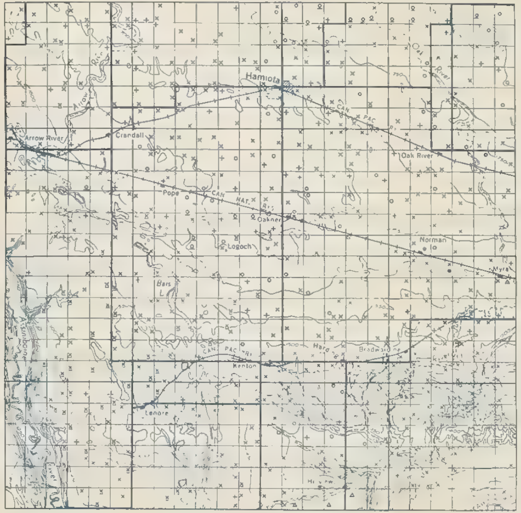
Gravel pit, in use or abandoned ⚒

Geological boundary (approximate)

BEDROCK FORMATIONS

The Upper Cretaceous, Riding Mountain formation of grey and greenish, siliceous shale underlies all of this area

FIGURE 2
MAP SHOWING TOPOGRAPHY AND LOCATION AND TYPES OF WELLS



LEGEND

● WELL, CLASS 1. Flowing artesian–water rises above the ground surface

○ WELL, CLASS 2. Sub-artesian–the water is under pressure but does not rise above the ground surface

× WELL, CLASS 3. Non-artesian–the water does not rise above the level of the water table

\+ Well that produces water, but for which information is scant or lacking

△ DRY HOLE

NOTE: A short dash under any symbol indicates that the well is in bedrock

Road

Railway

Contours (interval 50 feet)

Depression contour

TOWNSHIPS 11-14, RANGES 22-25

WEST OF PRINCIPAL MERIDIAN

MANITOBA

Scale: 1 Inch to 4 Miles

4 0 4 8 12

To accompany Water Supply Paper 315 "Hamiota Area" by E. C. Halstead

Cartography by the Geological Cartography Divn. 1953

WELL RECORDS

TOWNSHIPS 11-12-13-14 RANGES 18-19-20-21 WEST OF Princ. MER. PROVINCE MANITOBA

Well No.	LOCATION ¼	Sec	Tp	Rge.	Owner	DESCRIPTION Type	Elevation *	Depth (Feet)	Classification +	WATER LEVEL Above (+) Below (-) Surface	Elev. *	PRINCIPAL WATER-BEARING BED Depth (Feet)	Elev. *	Geological Horizon	WATER Quality	No. of dugouts	Use °	REMARKS
1	NW	1	11	18		bored	1275	33	NA	-28	1247	33	1242	gravel	hard, clear		DS	Sufficient supply
2	S.W.	1	"	"		drilled	1270	70	N.A.	-30	1240	70	1200	clay	" , iron		S.	" "
3	S.W.	1	"	"		bored	1274	40	N.A.	-20	1254	40	1234	fine sand	" , clear		D	"
4	N.W.	2	"	"		"	1290	65	N.A.	-20	1270	65	1225	clay	" , iron		D.S.	" "
5	N.W.	3	"	"		drilled	1312	65	NA			65	1247		" , clear		D	Can pump 3 pails a day
6	S.E.	3	"	"		"	1302	94	NA	-25	1277	94	1208	gravel	" , iron		DS	Sufficient supply
7	S.E.	4	"	"		bored	1302	44	N.F.A.	-9	1293	44	1258		" , clear		D.S.	" "
8	S.W.	4	"	"		drilled	1310	65	N.F.A.	-10	1300	65	1245	clay	" , iron.		S.	Sufficient for 25 head.
9	NW.	5	"	"		bored	1319	48	NA	-20	1299	48	1271		" , alkali		S	Sufficient supply
10	N.E.	5	"	"		"	1311	40	N.A.	-8	1303	40	1271	clay	" , "		S.	Dug well 12 ft. deep for house.
11	S.W.	6	"	"		dug	1321	30	N.A.	-22	1299	30	1291		" , clear	1	D.S	
12	NE	6	"	"		drilled	1320	75	NA	-50	1180	75	1245	gravel	" , "	1	DS	Sufficient supply.
13	N.E.	7	"	"		"	1324	76	N.A.	-20	1320	76	1248		" , iron	1	S.	Sufficient for 30 head.
14	S.W.	7	"	"		dug	1329	27	N.A.	-11	1318	27	1302		" , "	1	D.S.	" " 15
15	S.W.	8	"	"		"	1323	30	N.A.	-18	1305	30	1293	clay	" , clear		D.S.	Sufficient supply.
16	N.E.	8	"	"		drilled	1316	70				70	1246	gravel	" , alkali		D.S.	" "
17	S.W.	9	"	"		dug	1311	20				20	1291	clay	" , clear		D	Four such wells, no supply
18	NW	10	"	"		bored	1312	30	NA	-18	1294	30	1282	"	" , iron		S.	Sufficient for 20 head
19	S.E.	10	"	"		drilled	1304	50	N.A.	-30	1274	50	1254	black sand	" , "		DS	Sufficient supply
20	S.E.	11	"	"		"	1288	70	N.A.	-20	1268	70	1218	clay	" , "		D.S.	" "
21	S.W.	12	"	"		dug	1288	90	N.A.	-20	1268	90	1198		" , alkali		S.	" "
22	NE	13	"			bored	1337	60				60	1277	sand	, iron		DS	Sufficient for 20 head only
23	SW	13		"		drilled	1306	75	NA	-15	1291	75	1231	fine sand	" , "		S.	Sufficient supply
24	S.W.	13	"	"		"	1291	28				28	1211	gravel.	" , clear		D.	Well is near creek.
25	NE	14	"	"		dug	1321	53	NA	-28	1293	53	1268	clay	" , "		D.S	Sufficient supply
26	S.W.	14	"	"		"	1310.	35	N.A.	-8	1302	35	1275		" , iron		D.S.	" "
27	S.W.	15	"	"		bored	1314	30				30	1284	gravel.	" , "		N.	Well is caving.
28	NW	15	"	"		dug	1321	36	NA	-29	1292	36	1285	fine sand	" , "		S	Sufficient supply
29	S.W.	16	"	"		"	1305	27	N.A.	-16	1289	27	1278		" , "		S.	"
30	S.W.	16	"	"		"	1310	54	N.A.	-28	1282	54	1256		" , clear		S.	
31	S.E.	16	"	"		"	1307	20	N.A.	-18	1289	20	1287	sand.	" , iron		D.S.	Sufficient for 20 head.
32	N.E.	18	"	"		"	1329	10				10	1319		" , clear.		DS	Spring on creek bank
33	S.E.	19	"	"		bored	1354	70				70	1284		" , iron	1	D.S.	Not sufficient.
34	S.W.	20	"	"		dug	1347	40				40	1307	fine sand	" , clear		DS	Sufficient supply
35	NW	20	"	"		bored	1359	40	FA	-0	1359	40	1319	" "	" , iron		S	Well flows

* All elevations in feet above sea-level
\# Sample taken for analysis

\+ Classification F. A.-Flowing Artesian
N. F. A.-Non-Flowing Artesian
N. A.-Non-Artesian
I. N. A.-Intermittent Non-Artesian

° Use. S-Stock I-Irrigation M-Municipal D-Domestic
N-Not used G-Greenhouse or Garden

WELL RECORDS TOWNSHIPS 11 to 14 RANGES 18 to 21 WEST OF Princ. MER. PROVINCE MANITOBA

Well No	LOCATION ¼	Sec.	Tp	Rge	Owner	DESCRIPTION Type	Elevation *	Depth (Feet)	Classification +	WATER LEVEL Above (+) Below (−) Surface	Elev *	PRINCIPAL WATER-BEARING BED Depth (Feet)	Elev. *	Geological Horizon	WATER Quality	Temp. (in °F)	Use °	REMARKS
36	N.W.	21	11	18		dug	1338	37	N A	-11	1327	37	1301		hard, iron		D.S.	Two similar wells
37	N E	21	"	"		bored	1353	40	N A	-25	1328	40	1313	clay	" , "		D.S	Sufficient supply.
38	S.W.	22	"	"		dug	1347	35	N.A.	-10	1337	35	1312		" , clear		N.	
39	N.E.	23	"	"		bored	1336	60	N.F.A.	-9	1327	60	1276	fine sand.	" , iron		D.S	Well formerly overflowed.
40	N.E.	23	"	"		"	1342	40	N.A.	-10	1332	40	1302	" "	" , "		D.S.	Sufficient supply.
41	S.E.	23	"	"		"	1330	80				80	1250		" , alkali		D.S.	Drilled several wells.
42	N.E.	24	"	"		"	1347	65	N.A.	-25	1322	65	1282	clay	" , iron		D.S.	Sufficient for 12 head only.
43	S.W.	24	"	"		"	1330	35	N.A	-15	1315	35	1295	clay	" , "		S.	Sufficient supply.
44	S.W.	24	"	"		dug	1332	55	N.F.A.	-15	1317	55	1277	clay	" , "		D.	" "
45	S.W.	25	"	"		bored.	1351	54	N.A	-8	1343	54	1297		" , "		D.	" "
46	N.E.	25	"	"		"	1365	44	N.A.	-22	1353	44	1321		" , "		N.	
47	S.W.	26	"	"		"	1359	40	N.A.	-20	1339	40	1319	clay	" , "		D.S.	Sufficient supply.
48	S.W.	27	"	"		"	1367	75				75	1292	sand	" , "		D.S.	" "
49	N.W.	27	"	"		"	1375	68				68	1307	sand.	" , "		D.S.	Sufficient for 20 head.
50	S.E.	28	"	"		"	1360	52	N.A.	-10	1350	52	1308	clay	" , "		N.	
51	N.W.	28	"	"		"	1365	52	N.A.	-32	1333	52	1313	sand.	" , "			
52	N.W.	28	"	"		drilled	1373	130	N.A	-65	1308	65	1308		" , alkali		S.	Sufficient supply.
53	S.E.	29	"	"		bored.	1376	75	N.A.	-20	1356	75	1301	sand.	" , iron		S.	Sufficient for 10 head.
54	N.E	30	"	"		"	1388	70				70	1318	clay	" , "		S.	Sufficient supply.
55	S.E	30	"	"		dug	1383	17	N.A.	-9	1374	17	1366	"	" , clear		N.	
56	S.W.	30	"	"		bored.	1395	65	N.A.	-20	1375	65	1330	"	" , iron		D.S.	Sufficient supply.
57	S.E	31	"	"		"	1408	50	N.A.	-10	1398	50	1358	"	" , "		S.	Sufficient for 25 head.
58	S.W.	31	"	"		"	1434	51	N.A.	-9	1425	51	1383		" , "		N.	
59	N.W.	31	"	"		"	1439	48				48	1391		" , "		D.S.	Sufficient for 15 head only.
60	N.W	32	"	"		"	1433	80	N.A	25	1408	80	1353	clay	, "		D.S	Sufficient supply.
61	S.W.	32	"	"		"	1394	60	N.A.	-15	1379	60	1334	"	" , "		S.	" "
62	N.E	32	"	"		"	1413	60	N.A	-30	1383	60	1353	sand			D.S	Sufficient for 50 head
63	S.W.	33	"	"		"	1405	38	N.A.	-17	1388	38	1367	gravel	" , "		D.S.	" " 50 "
64	S.E.	33	"	"			1418	44	N.A	-22	1396	44	1374	clay	" , clear		D.S	Sufficient supply.
65	S.W	34	"	"		dug	1405	40	N.A	-18	1387	40	1365		" , alkali		S	Sufficient for 25 head
66	N.W.	35	"	"		bored	1422	40	N.A	25	1397	40	1382		" iron		D.S	Sufficient supply.
67	S.E.	35	"	"		"	1376	42	N.A	-20	1356	42	1334		" , "		S.	" "
68	S.W.	36	"	"		"	1388	37	N.A.	-14	1374	37	1351		" , "		N.	

* All elevations in feet above sea-level
\# Sample taken for analysis

\+ Classification. F. A.–Flowing Artesian
N. F. A.–Non-Flowing Artesian
N. A.–Non-Artesian
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° Use: S–Stock I–Irrigation M–Municipal D–Domestic
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WELL RECORDS TOWNSHIPS 11 to 14 RANGES 18 to 21 WEST OF Princ. MER. PROVINCE MANITOBA

No.	LOCATION ¼	Sec	Tp	Rge	Owner	DESCRIPTION Type	Elevation *	Depth Feet	Classification +	WATER LEVEL Above (+) Below (-) Surface	Elev *	PRINCIPAL WATER BEARING BED Depth Feet	Elev *	Geological Horizon	WATER Quality	No. of Dugouts	Use ○	REMARKS
1	N.E.	1	12	18		bored	1431	20	N.A.	-16	1415	20	1411		hard, clear		D.S.	Not sufficient.
2	S.W.	1	"	"		"	1408	24	N.A.	-12	1396	24	1384	fine sand.	" , "		D.S.	Sufficient supply.
3	S.W.	2	"	"		"	1437	44	N.A.	-6	1431	44	1393		" , iron		D.S.	" "
4	N.W.	2	"	"		"	1445	30	N.A.	-14	1431	30	1415	clay	" , "		D.S	
5	S.E.	3	"	"		dug	1439	40				40	1399		" , "	1	D.S.	" "
6	N.E.	3	"	"		drilled	1466	50	N.A.	-25	1441	50	1416		" , "		D.S.	
7	S.W.	3	"	"		bored	1438	40	N.A.	-37	1401	40	1398		" , "		D.S.	" "
8	S.W.	5	"	"		"	1441	62	N.A.	-28	1413	62	1379	clay.	" , "		D.S.	Sufficient for 100 head.
9	S.E.	5	"	"		"	1465	26	N.A.	-9	1456	26	1439		" clear.		N.	Too alkali to use.
10	N.W.	6	"	"		dug	1481	27	N.A.	-23	1458	27	1454		" , iron		D.	A similar dug well for stock
11	S.W.	6	"	"		bored	1459	48	N.A.	-20	1439	48	1411		" , alkali		D.S	Sufficient supply.
12	NE	7	"	"		"	1525	26	NA	23	1502	26	1499	gravel	" , clear	1	D S	Sufficient for 20 head
13	NW	8				drilled	1494	125	NFA	-25	1469	125	1369		, alkali		S	Dug well 12 ft for house
14	S W	9				bored	1488	73	NA	-23	1465	73	1415		, iron		S	Sufficient supply
15	S.E.	10	"	"		dug	1475	40	N.A.	-23	1452	40	1435		" , "		D.S.	Sufficient for 20 head.
16	SE	11	"	"		drilled	1447	26	NA	-15	1432	26	1421	gravel.	,		DS	Sufficient supply
17	NW	11	"	"		dug	1450	8	F.A.	0	1450	8	1442	clay	" , "		D.S.	" "
18	NW.	12	"	"		bored	1452	60	N.A.	-20	1432	60	1392	"	" , "	1	S.	" "
19	S.E.	14	"	"		"	1474	60				60	1414	"	" , "		D.S.	" "
20	SE	15					1476	50	NA	-16	1460	50	1426	sand	,		D S	Also a bored well 46 ft deep
21	S.W.	16	"	"		"	1512	46	N.A.	-35	1477	46	1466	clay.	" , "		D.S.	Sufficient for 70 head.
22	NW.	16	"	"		"	1531	65	NA.	-45	1486	65	1466	"	" , "		D.S.	Sufficient supply.
23	N.E.	17	"	"		"	1547	75	N.A.	-45	1502	75	1472	"	" , "		S.	" "
24	NW	17	"	"		"	1547	70	N.A.	-30	1517	70	1477	gravel.	" , "		D.S.	Sufficient for 100 head.
25	S.W.	18	"	"		drilled	1530	80	N.A.	-35	1495	80	1450	"	" , "	1	D.S.	Sufficient supply.
26	NW	18	"	"		bored	1562	83	NA	-53	1509	83	1479		, alkali		N	
27	NW	19	"	"		"	1592	70	N.A.	-40	1552	70	1522	gravel.	" , "		D.S.	Sufficient for 50 head.
28	N.E.	19	"	"		"	1588	75	N.A.	-50	1538	75	1513	fine sand.	" , iron.		S.	Sufficient supply.
29	SE.	21	"	"		"	1545	51	N.A.	-25	1520	51	1494		" , "		S.	"
30	N.E.	20	"	"		"	1574	98	N.A.	-40	1534	98	1476		" , "		D.S.	Sufficient for 30 head.
31	SW	21	"	"		dug	1539	15	NA	-7	1532	15	1524	sand	, clear		D S	Sufficient supply
32	SW	21				bored	1579	47	NA	-27	1562	47	1502		, black		N	
33	N.W	22	"	"		bored	1519	32	N.A.	-30	1489	32	1487	gravel.	" , iron		D.S.	Not sufficient.
34	NW	22	"	"		"	1524	40	N.A.	-36	1488	40	1484	"	" , "		D.S.	" "
35	SE	22	"	"		dug	1506	9	NA.	-6	1500	9	1497	fine sand	" , clear		D S	Sufficient supply

* All elevations in feet above sea level
# Sample taken for analysis

+ Classification: F.A.-Flowing Artesian; N.F.A.-Non-Flowing Artesian; N.A.-Non-Artesian; I.N.A.-Intermittent Non-Artesian

○ Use: S-Stock I-Irrigation M-Municipal D-Domestic N-Not used G-Greenhouse or Garden

WELL RECORDS TOWNSHIPS 11 to 14 RANGES 18 to 21 WEST OF Princ. MER. PROVINCE MANITOBA

No.	¼	Sec.	Tp.	Rge.	Owner	Type	Elevation	Depth Feet	Class	Above (+) Below (-) datum	Elev.	Depth (Feet)	Elev.		Quality	No. of dugouts	Use	REMARKS
	LOCATION					DESCRIPTION				WATER LEVEL		PRINCIPAL WATER-BEARING BED			WATER			
36	NW	23	12	18		dug		8		-7		8		gravel	hard, clear		DS	Sufficient supply
37	SE	24				bored	1498	45	NA	-20	1478	45	1453	gravel	, alkali		DS	Sufficient for 25 head
38	N.E.	24	"	"		dug	1497	13	NA	-6	1491	13	1484	"	" , clear		D.S.	" " 50
39	N.W.	24	"	"		"	1523	28	N.A.	-25	1498	28	1495	clay	" , "		D.	Stock well dug 60 feet
40	SE	25				bored	1511	50	NA	-5	1506	50	1461				DS	Had a flowing well 50 feet
41	SW	25					1536	46	NA	-20	1516	46	1490	sand	, iron		DS	Sufficient supply.
42	N.E.	26	"	"		dug	1534	6	N.A.	-4	1530	6	1529	sand	" , clear		D.S.	" "
43	NW	26	"	"		"	1574	84	NA	-60	1514	84	1490	clay	, iron	1	S	Sufficient for 15 head only
44	NE	27				drilled	1582	100				100	1482	"	,	1	D.S.	Sufficient supply
45	SW.	27	"	"		bored	1570	60	N.A.	-58	1512	60	1510		" , "		D.	Not sufficient.
46	S.E.	29	"	"		"	1575	70	N.A.	-9	1566	70	1505	fine sand.	" , "	1	S.	Sufficient for 25 head.
47	N.W.	30	"	"		"	1643	57	N.A.	-54	1589	57	1586	clay	" , "	1	N.	
48	S.W.	31	"	"		"	1647	100	N.A.	-20	1627	100	1547	"	" , "	1	S.	Also a bored well 90 ft.
49	S.E.	32	"	"		"	1625	120	N.A.	-70	1555	120	1505	"	" , "	1	D.	Not sufficient.
50	SW	32				drilled	1613	125	NA	-60	1553	125	1488	black sand			DS	Sufficient supply
51	S.E.	33	"	"		drilled.	1612	120	N.A.	-60	1552	120	1492	" "	" , "	1	S.	
52	SE	35				bored	1572	72	NA	-50	1522	72	1500	sand	,		DS	Sufficient supply
53	SE	36				dug	1524	15	NA	-4	1520	15	1509	"	, clear		D.S.	Sufficient for 10 head.
54	N.E.	36	"	"		"	1538	12	N.A.	-6	1532	12	1526	gravel.	" , "		D.S.	" " 100 "
1	SE	1	13	18		bored	1553	63	NA	-34	1519	63	1490	clay	hard, iron	1	S	Sufficient supply
2	SW.	4	"	"		drilled	1640	160?							" , "	1	D.	" "
3	N.E.	6	"	"		dug	1699	14	N.A.	-5	1694	14	1685	clay	" , clear	1	D.	Dug several dry holes.
4	S.W.	7	"	"		"	1713	16				16	1697	"			N.	Drilled 81 feet, dry hole.
5	NE	10					1654	15	NA	-5	1649	15	1639		hard, clear	1	D	Sufficient supply
6	S.E.	14	"	"		"	1650	35	N.A.	-8	1642	35	1615		" , "	1	D.S.	" "
7	N.W.	15	"	"		"	1677	15				15	1662	sand.	" , "	1	D.	
8	N.W.	16	"	"		"	1708	20	N.A.	-14	1694	20	1688	clay	" , "	1	D.	
9	N.E.	17	"	"		"	1721	18				18	1703	"	" , "	1	D.S.	Not sufficient.
10	NE	18					1746	11	NA	-5	1741	11	1735	fine sand			D.S.	Sufficient supply
11	SW	18					1721	20	NA	-3	1718	20	1701	clay	,	1	S	Sufficient for 20 head
12	NW	19				bored	1764	75	NA	-15	1744	75	1689	gravel	, iron			Not good water
13	NE	22				dug	1707	20	N.A	-15	1692	20	1687	clay	, clear	2	D.	Drilled 325 feet
14	N.W.	27	"	"		"	1727	12				12	1715	"	" , "	1	D.	
15	S.W.	29	"	"		"	1722	12	N.A	-10	1712	12	1710	"	" , "	1	D.	

Sample taken for analysis

F.A.-Flowing Artesian
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WELL RECORDS TOWNSHIPS 11 to 14 RANGES 18 to 21 WEST OF Princ. MER PROVINCE MANITOBA

	Well No	LOCATION ¼	Sec	Tp.	Rge	Owner	DESCRIPTION Type	Elevation *	Depth (Feet)	Classification +	WATER LEVEL Above (+) Below (-) Surface	Elev. *	PRINCIPAL WATER-BEARING BED Depth (Feet)	Elev. *	Geological Horizon	WATER Quality	No. of dugouts	Use °	REMARKS
	16	NW	31	13	18		dug	1752	16	N.A.	-13	1739	16	1736	fine sand	hard, iron		DS	Sufficient supply
	17	N.E.	32	"	"		"	1785	12				12	1773	gravel.	" , clear		D.	" "
	18	N.W.	33	"	"		bored	1754	70	N.A.			70	1684	sand.	" , alkali	1	S.	Sufficient for 12 head.
#	19	S.W.	34	"	"		dug	1757	12	N.A	-8	1749	12	1745	gravel	" , clear	1	D	Sufficient supply
	1	S.W.	3	14	18		dug	1759	12	N.A	-10	1749	12	1747	clay	hard, clear	1	D	Decreases seasonally.
	2	NE	5		"		drilled	1804	102				102	1702	fine sand	" , "	1	DS	Drilled a dry hole 300 ft deep.
	3	NW	6		"		bored	1819	32	N.A	-30	1789	32	1787	gravel	" , "		DS	Not sufficient
	4	SE.	9	"	"		dug	1783	30	N.A	-4	1779	30	1753		" , alkali	1	D	Sufficient supply
	5	N.W.	12	"	"		"	1731	12				12	1719	gravel.	" , clear	1	D.	" "
	6	S.W.	16	"	"		bored	1843	60	N.A.	-35	1808	60	1783	fine sand.	" , iron.		D.S.	" "
	7	N.W.	18	"	"		dug	1786	9				9	1777	gravel	" , clear		D.S.	" "
	8	N.E.	18	"	"		"	1796	12	N.A.	-8	1788	12	1784	"	" , iron.		D.S.	" "
	9	N.W.	19	"	"		"	1783	14				14	1769	"	" , clear		D.S.	Sufficient for 50 head.
	10	S.W.	20	"	"		"	1836	28	N.A	-25	1811	28	1808	sand	" , "	1	D.S	Sufficient supply.
	11	SE	20	"	"		bored	1832	60	N.A.	-40	1792	60	1772	fine sand	" , "	1	DS	Sufficient for 40 head.
	12	S.E	21	"	"		dug	1830	20				20	1810	clay	" , "	1	DS	Sufficient supply.
	13	S.W	21	"	"		bored	1835	55	N.A	-10	1825	55	1780	sand	" , "	1	DS	Sufficient for 10 head only
	14	NW	22	"	"		dug	1801	15	N.A	10	1791	15	1786	gravel	" , "	1	D	No supply in drier years
	15	SW	27	"	"			1795	12				12	1783	clay	" , "	1	D.S	Not sufficient.
	16	NW	28	"	"		"	1833	15	N.A	-12	1821	15	1818		" , "		DS	Sufficient supply
	17	S.E.	30	"	"		"	1813	30	N.A.	-26	1787	30	1783	gravel.	" , "	1	D.S.	Not sufficient.
	18	NW	33	"	"		"	1817	15	N.A	-9	1808	15	1802		" , "		D	Sufficient supply.
	19	N.W.	34	"	"		"	1773	12	N.A.	-10	1763	12	1761	sand.	" , "	1	D.S.	" "
	1	SW	1	11	19		dug	1326	22				22	1304	fine sand	hard, clear		DS	Sufficient for 10 head, only.
	2	NE	1	"	"		drilled	1318	60				60	1258		iron	1	S	Dug well 30 feet for drinking
	3	NW	2	"	"		dug	1348	55				55	1293		" , clear		D.S.	Sufficient for 25 head only
	4	S.E.	2	"	"		drilled	1331	46	N.A.	-21	1310	46	1285		" , "		D.S.	" " 65 "
	5	S.E	3	"	"		"	1333	35	N.A	-10	1323	35	1298	gravel.	" , iron		S.	" " 40 " only.
	6	S.W.	4	"	"		dug	1360	15	N.A.	-12	1348	15	1345	sand.	" , clear		S.	" " 50 "
	7	S.E	5	"	"		"	1362	16	N.A	-14	1348	16	1346	"	" , "		D	Sufficient supply
	8	NE	6	"	"		"	1413	26	N.A	-14	1399	26	1387		"		DS	Has watered 60 head
	9	NE	8	"	"			1362	15				15	1347		"		DS	Sufficient for 100 head
	10	S.W.	9	"	"		"	1364	20	N.A	-17	1347	20	1344		"	1	DS	Sufficient supply.

* All elevations in feet above sea-level
\# Sample taken for analysis

\+ Classification: F. A.–Flowing Artesian
N. F. A.–Non-Flowing Artesian
N. A.–Non-Artesian
I. N. A.–Intermittent Non-Artesian

° Use: S–Stock I–Irrigation M–Municipal D–Domestic
N–Not used G–Greenhouse or Garden

WELL RECORDS TOWNSHIPS 11 to 14 RANGES 16 to 21 WEST OF Princ. MER PROVINCE MANITOBA

	LOCATION					DESCRIPTION				WATER LEVEL		PRINCIPAL WATER-BEARING BED			WATER			REMARKS
Well No	¼	Sec	Tp	Rge	Owner	Type	Elevation *	Depth (feet)	Classification +	Above (+) Below (-) Surface	Elev *	Depth (Feet)	Elev *	Geological Horizon	Quality	No. of dugouts	Use o	
11	SE	10	11	19		drilled	1350	58	N F A	-15	1335	58	1292	sand	hard iron		S	Sufficient supply
12	S.W.	11	"	"		bored	1348	70				70	1278		" , "		S.	" "
13	S.W.	12	"	"		dug	1349	20				20	1329	gravel.	" , clear		D.	" "
14	SE	16				bored	1337	60	NFA	-15	1322	60	1277	sand	"		D S	Sufficient for 40 head
15	S.W	17	"	"		dug	1369	12	N.A	-9	1360	12	1357	fine sand.	" , "	1	D.S	" " 4 " only.
16	S.E.	18	"	"		"	1372	10	N.A.	-6	1366	10	1362	sand	" , "		D.S.	Sufficient supply.
17	N.E.	18	"	"		"	1549	53	N.A.	-45	1504	53	1496	clay	" , iron		D.S.	Sufficient for 65 head.
18	S.W.	21	"	"		bored.	1361	67	N.A.	-63	1298	67	1294	"	" , alkali		D.S.	Sufficient supply.
19	S.E.	22	"	"		dug	1357	24	N.A.	-18	1339	24	1333	"	" , iron.		S.	" "
20	N.E.	22	"	"		"	1388	25	N A	-18	1370	25	1363	"	" , "		S.	" "
21	N.W	23	"	"		"	1366	36	F.A	+6 inches	1366	36	1330	"	" , "		S.	" "
22	NW	24	"	"		"	1368	47	F.A.	0	1368	47	1321	"	" , "		S.	" "
23	S.E.	25	"	"		drilled.	1395	100?							" , "		D.S.	" "
24	S.W.	25	"	"		dug	1409	40	N.A.	-35	1374	40	1369		" , "		D.S.	" "
25	N.W	26	"	"		"	1413	40				40	1373		" , "		S.	
26	N.E.	27	"	"		drilled.	1410	86	N.A.	-30	1380	86	1324	clay	" , "	1	D.S.	Sufficient for 25 head
27	SE	27				bored	1401	36	N A	-12	1389	36	1365				D S	Sufficient supply.
28	N.W	28	"	"		"	1471	62	N.A.	-57	1414	62	1409	sand.	" , "	1	D.S.	Sufficient for 50 head.
# 29	S.W	28	"	"		dug	1433	50	N A.	-46	1387	50	1383	"	" , clear		D.S.	Sufficient supply.
30	S.W.	29	"	"		bored.	1550	70	N A.	-28	1522	70	1480	clay	" , alkali	1	S.	" "
31	N.E	30	"	"		"	1582	56	N.A.	-47	1535	56	1526		" , clear		S.	" "
32	N.W.	30	"	"		drilled	1569	75	N.A.	-40	1529	75	1494	clay	" , iron	1	S.	Sufficient for 12 only.
33	SE	30				bored	1542	70	N A	-17	1525	70	1472		" , "		S	15 head
34	N.E.	31	"	"		"	1479	60	N.A.	-13	1466	60	1419	sand.	" , "		D S	Sufficient supply.
35	S.E.	33	"	"		"	1437	78	N.A.	-25	1412	78	1359	"	" , "	1	S.	Sufficient for 50 head.
36	N.E.	34	"	"		"	1458	85	N.A	-25	1433	85	1373		" , clear	1	S.	" " 15 " .
37	N.E.	35	"	"		"	1468	70	N.A.	-28	1440	70	1398		" , iron	1	D.S	Sufficient supply.
38	S.E.	36	"	"		"	1428	50	N.F.A.	-3	1425	50	1378		" , "		N.	
# 39	S.W	36	"	"		drilled	1438	54	N.A.	-30	1408	54	1384		" , "	1	D.S.	Sufficient supply.
1	S E	2	12	19		bored	1481	85	N F A	-15	1466	85	1396		hard, iron	1	D S	Sufficient supply
2	S.E.	3	"	"		dug	1477	80				80	1397		" , "		D.S.	" "
3	S.W.	4	"	"		bored.	1468	70	N.A.	-25	1443	70	1398	gravel.	" , "		D.S.	" "
4	S.E.	5	"	"		drilled	1474	90				90	1384	clay	" , "	1	S.	" "
5	NE	6	"			dug	1498	80	N A	-70	1428	80	1418		" , "		S	Sufficient for 10 head

* Elev. from [illegible]
# Sample taken for analysis

+ Classification F.A.-Flowing Artesian
N.F.A.-Non-Flowing Artesian
N.A.-Non-Artesian
I.N.A. [illegible]

o Use S-Stock I-Irrigation M-Municipal D-Domestic
N-Not used G-Greenhouse or Garden

WELL RECORDS   TOWNSHIPS 11 to 14   RANGES 18 to 21   WEST OF Princ. MER.   PROVINCE MANITOBA

Well No.	LOCATION ¼	Sec.	Tp.	Rge.	Owner	DESCRIPTION Type	Elevation *	Depth (Feet)	Classification +	WATER LEVEL Above (+) Below (-) Surface	Elev. *	PRINCIPAL WATER-BEARING BED Depth (Feet)	Elev. *	Geological Horizon	WATER Quality	No. of dugouts Temp. (in °F)	Use ○	REMARKS
6	S.E.	7	12	19		drilled	1491	125				125	1366	sand	hard, iron			Supplies about 2 barrels a day
7	S.W.	7	"	"		bored	1527	69	N.A	-10	1517	69	1458		" ,clear			Stagnant odour
8	S.E.	8	"	"		drilled	1498	140	N.A.	-70	1428	140	1358	sand.	" ,iron		D.S.	Sufficient for 30 head.
9	S.W.	8	"	"		bored	1530	48	N.A.	-12	1518	48	1482	clay	" ,alkali		S.	" " 10 " only.
10	N.E.	9	"	"		"	1540	115	N.A.	-40	1500	115	1425	sand	" ,iron		D.S.	Sufficient supply.
11	N.W.	10	"	"		drilled	1536	117	N.A.	-52	1484	117	1419	sand.	" ,clear		N.	
12	S.E.	12	"	"		bored.	1508	50	N.A.	-28	1480	50	1458		" , "		S.	Sufficient for 30 head.
13	N.E.	12	"	"		dug	1531	22	N.A.	-12	1519	22	1509		" , "		D.	Sufficient supply.
14	S.E.	13	"	"		bored	1550	28	N.A	-26	1524	28	1522	fine sand	" ,	1	D.S	Sufficient for 4 head only.
15	S.W.	15	"	"		"	1576	138	N.A.	-66	1510	138	1438	sand.	" , "		D.S.	Sufficient supply.
16	S.W.	16	"	"		drilled	1558	180				180	1378		" ,iron		D.S.	" "
17	S.E.	17	"	"		"	1569	288	N.A.	-40	1529	288	1281	shale	" ,alkali	1	D.S.	" "
18	S.E.	18	"	"		"	1577	45	N.A.	-20	1557	45	1532	clay.	" ,iron.		S.	Sufficient for 100 head.
19	S.E.	19	"	"		dug	1611	17	N.A.	-9	1602	17	1594	sand.	" ,clear	1	D.S.	Sufficient supply.
20	S.W.	19	"	"		"	1610	23	N.A.	-9	1601	23	1587		" ,iron	1	S.	
21	N.E.	20	"	"		drilled	1634	85	N.A.			85	1549	fine sand.	" , "	3	D.	Supplies 2 barrels a day.
22	S.E.	20	"	"		bored	1611	68	N.A	-52	1559	68	1543		" ,alkali	1	S.	Not sufficient.
23	S.W.	20	"	"		"	1600	130	N.A.	-40	1560	130	1470		,clear		D.S	Sufficient for 40 head
24	S.E.	21	"	"		"	1615	70	N.A.	-65	1550	70	1545	sand.	" , "	1	D.	Sufficient for house only.
25	N.E.	21	"	"		"	1639	65	N.A.	-25	1614	65	1574	clay	" ,iron	1	D.	Sufficient supply.
26	S.E.	24	"	"		"	1581	90				90	1491		" , "	1	N	
27	N.E.	25	"	"		"	1639	22	N.A.	-6	1633	22	1617	clay	" ,clear	1	D.	Drilled a dry hole 300 feet
28	N.E.	26	"	"		"	1642	60				60	1582	"	" , "	1	N	
29	N.W.	27	"	"		"	1657	65				65	1592	gravel.	" ,iron	1	D.S.	Sufficient for 20 head only.
30	S.W.	29	"	"		"	1650	54	N.A.	-20	1630	54	1596	"			N.	Well just dug.
31	N.W.	29	"	"		"	1678	80?							hard, clear	1	D.S.	Sufficient for 10 head only.
32	N.E.	32	"	"		"	1707	60	N.A.	-35	1672	60	1647	clay	" ,iron	1	D.S.	Sufficient supply.
33	N.W.	33	"	"		"	1694	90	N.A.	-80	1614	90	1604	"	" , "		S.	" "
34	N.W.	34	"	"		dug	1689	12	N.A.			12	1677	fine sand.	" , "		D.S	
35	N.W.	35	"	"		"	1703	16	N.A.			16	1697	gravel.	" ,clear		D.S	
1	N.E.	2	13	19		dug	1703	10	N.A.	-5	1698	10	1693	clay	hard, alkali		N.	
2	S.W.	2	"	"		"	1697	5				5	1692	gravel.	" ,clear		D.S.	Well is in a gravel pit.
3	N.E.	2	"	"		"		20		-10		20		"	" , "		S.	Sufficient for 30 head.
4	S.W.	4	"	"		bored	1710	65	N.A	-15	1695	65	1645	clay	" , "		D.S	" 15 "

* All elevations in feet above sea-level
\# Sample taken for analysis

\+ Classification: F.A.–Flowing Artesian
N.F.A.–Non-Flowing Artesian
N.A.–Non-Artesian
I.N.A.–Intermittent Non-Artesian

○ Use: S–Stock I–Irrigation M–Municipal D–Domestic
N–Not used G–Greenhouse or Garden

WELL RECORDS TOWNSHIPS ...11 to 14... RANGES ..18 to 21....... WEST OF..Princ....MER. PROVINCE ..MANITOBA..

Well No.	¼	Sec	Tp	Rge.	Owner	Type	Elevation *	Depth (Feet)	Classification +	Above (+) Below (-) Surface	Elev. *	Depth (Feet)	Elev. *	Geological Horizon	Quality	No. of dugouts	Use °	REMARKS
	LOCATION					DESCRIPTION				WATER LEVEL		PRINCIPAL WATER-BEARING BED			WATER			
5	SW	4	13	19	School Well	bored	1709	21	NA	-7	1702	21	[illegible]		hard clear		D	Sufficient supply
6	N.W.	5	"	"		drilled	1719	70	N.A.	-30	1689	70	1649	sand	" , "		D.S.	" "
7	N.E.	6	"	"		"	1711	70	N.A	-21	1690	70	1641		" , "		D.S.	Sufficient for 20 head.
8	N.E.	7	"	"		dug	1701	48	N.A.	-10	1691	48	1653	gravel	" , "		D.	Sufficient supply.
9	N.E.	8	"	"		bored	1753	35	N.A.	-18	1735	35	1718		" , "		D.S.	Sufficient for 60 head.
10	N.W.	8	"	"		"	1742	58	N.A.	-50	1692	58	1684	sand.	" , "		D.S.	" " 10 " only.
11	N.W.	9	"	"		"	1755	75	N.A.	-20	1735	75	1680		" ,iron		D.S.	Sufficient supply.
12	N.E.	9	"	"		dug	1758	46	N.A.	-18	1740	46	1712		" ,clear		N.	
13	N.W.	10	"	"		"	1766	24	N.A.	-5	1761	24	1742	clay	" , "		S.	Not sufficient.
14	S.W.	10	"	"		bored	1757	16				16	1741		" ,odour	1	N.	
15	S.E.	11	"	"		dug	1735	11	N.A.	-8	1727	11	1724	clay	" ,clear	1	D.	Sufficient supply.
16	N.W.	11	"	"		"	1769	20				20	1749	"	" , "	1	S.	Bored a dry hole 100 feet.
17	N.W.	16	"	"		bored	1745	20	N.A.	-5	1740	20	1725		" , "		D.	Sufficient supply.
18	N.E.	16	"	"		"	1760	25	N.A.	-15	1745	25	1735	fine sand	" , "	1	D.	" "
19	S.E.	16	"	"		drilled	1764	64				64	1700	gravel	" ,iron		D.S.	
20	N.E.	17	"	"		dug	1705	30	N.A.	-24	1681	30	1675		"		N.	
21	SW	17	"				1689	18	NA	-2	1687	18	1671	clay	hard,clear		D S	Sufficient for 15 head
22	S.E.	21	"	"		"	1745	14	N.A.	-11	1734	14	1731	gravel	" , "		D.S.	Sufficient supply.
23	NE.	21	"	"		"	1749	9				9	1740		" , "		D	
24	NW.	22	"	"		"	1785	22	N.A.	-16	1769	22	1763		" , "		D.S.	Sufficient for 20 head.
25	NE	22	"	"		"	1804	14	N A	-12	1792	14	1790	gravel	" , "		D.S	Sufficient supply
26	NW	23	"	"		"	1829	26	N.A.	-22	1807	26	1803	"	" , "		D.S.	"
27	N.E.	23	"	"		"	1837	60+	N.A.	-20	1817	60	1777	fine sand.	" ,iron		D.S	
28	SW	26	"	"		"	1836	23	N.A.	-20	1816	23	1813	gravel.	" ,clear		D.S	
29	S.E	27	"	"		"	1796	16	N.A.	-13	1783	16	1780	"	" , "		D.S.	
30	S.E.	28	"	"		"	1727	35	N.A.	-31	1696	35	1692		" , "		D.S.	
31	S.W.	33	"	"		"	1782	16				16	1766	gravel.	" , "	1	D.	
1	NE	1	14	19		bored	1815	26	N A	-10	1805	26	1789	fine sand	hard,clear		D.S.	Drilled 2 dry holes 81 and 110'
2	S.W.	1	"	"		dug	1764	16	N.A	-13	1751	16	1749	clay	" , "		D.S.	Sufficient supply.
3	S.E.	2	"	"		"	1639	12	N.A	-8	1631	12	1627	shale	" , "		D.S.	Sufficient for 100 head.
4	NW	3					1817	12	NA	4	1813	12	1805	gravel	" ,		D	Well is in a gravel pit
5	SE	8	"				180[illegible]	10	NA	5	1800	10	1795				N	
6	NW	12				"	1801	12	NA	8	1773	12	1789	[illegible] sand	hard clear		D S	Sufficient supply
7	NW	13	"				1707	17	NA	9	1698	17	1690		,			

* [illegible] above sea level
Sample taken for analysis

+ Classification F.A.-Flowing Artesian
N. F. A.-Non-Flowing Artesian
N. A.-Non-Artesian
I. N. A.-Intermittent Non-Artesian

° Use. S-Stock I-Irrigation M-Municipal D-Domestic
N-Not used G-Greenhouse or Garden

WELL RECORDS

TOWNSHIPS 11 to 14 RANGES 18 to 21 WEST OF Princ. MER. PROVINCE MANITOBA

Well No.	LOCATION ¼	Sec.	Tp	Rge.	Owner	DESCRIPTION Type	Elevation *	Depth (Feet)	Classification +	WATER LEVEL Above (+) Below (–) Surface	Elev. *	PRINCIPAL WATER BEARING BED Depth (Feet)	Elev. *	Geological Horizon	WATER Quality	Temp. (in °F) No. of dugouts	Use °	REMARKS
8	NE	13	14	19		dug	1755	16	N.A.	-12	1743	16	1739	fine sand.	hard,clear		D.S.	Sufficient supply.
9	S.W.	23	"			"	1632	36	N.A.	-21	1611	36	1596	sand.	" , "		D.S.	" "
10	NE	30	"	"		"	1875	28	N.A.	-12	1863	28	1847	gravel	" , "		D.S.	Sufficient for 6 horses only in dry years.
11	NW	31	"			drilled	1920	105	N.F.A.			105	1815	clay	" ,iron		D.S.	Sufficient supply.
12	NW	33	"	"		"	1903	200				200	1703		" ,clear		D.S.	" "
1	S.E.	1	11	20		dug	1430	24	N.A.	-9	1421	24	1406		hard,clear		D.S.	Sufficient supply.
2	N.E	1	"	"		"	1396	14	N.A.	-10	1386	14	1382		" , "		D.S.	" "
3	N.W	2	"	"		"	1399	15				15	1384	gravel	" , "		D.S.	Not sufficient.
4	NW	3	"	"		"	1428	14	NA	-7	1421	14	1414	"	" , "	1	DS	Sufficient for 20 head
5	N.W	4	"			"	1428	10				10	1420	"	" ,	1	DS	" 20 " only.
6	SW.	5	"	"		"	1406	14	NA	-7	1399	14	1392	clay	" , "		D.S.	Sufficient supply
7	N.E.	5	"	"		"	1411	20	N.A.	-3	1408	20	1391	"	" , "		D.S.	" "
8	SE.	6	"	"		"	1411	18	NA	-10	1401	18	1393	sand	" ,iron		S	Sufficient for 50 head
9	NE	8	"	"		drilled	1395	135	NFA	-80	1315	135	1260	gravel	" "		DS	Sufficient supply
10	NE	9	"	"		dug	1262	15	NA	-12	1250	15	1247	sand	" ,clear		DS	" "
11	S.E.	13	"	"		"	1482	14	N.A.	-11	1471	14	1468		" , "		D	" "
12	N.E.	14	"	"		"	1377	10	N.A.	-7	1370	10	1367	fine sand	" , "		D.S.	Sufficient for 20 head.
13	SW	14	"	"		"	1375	20	N.A.	-6	1369	20	1355		" , "	1	S	
14	SW	15	"	"		bored	1328	72	N.A.	-12	1316	72	1256	shale	" , "		D.S.	Sufficient supply.
15	SW	17	"	"		drilled	1408	150	N.A	-100	1308	150	1258	sand.	" ,iron		D.S.	Sufficient for 50 head
16	SW	18	"	"		"	1434	175	N.F.A.	-35	1399	175	1259	fine sand	" , "			Fills in with sand.
17	SW.	18	"	"		dug	1404	20	NA	-10	1394	20	1384	sand.	soft,clear		D	Sufficient supply.
18	NW	19	"	"		"	1318	26	N.A.	-22	1296	26	1292		hard, "		D.S.	Sufficient for 10 head.
19	NW.	21	"	"		"	1414	40	N.A.	-25	1389	40	1374	fine sand	" , "		S.	" " 25 " only.
20	SW	21	"	"		"	1328	40	N.A.	-30	1298	40	1288	sand.	" , "		D.S.	" " 30 " "
21	SW	22	"	"		drilled	1391	125	NA	-100	1291	125	1266	fine sand	" ,iron		S	Sufficient supply
22	SW	23	"	"		dug	1394	50	N.A.	-40	1354	50	1344		" , "	1	D.S.	Sufficient for 50 head.
23	SW	24	"	"		bored	1523	60	NA	-50	1473	60	1463	sand	" ,clear	1	DS	Sufficient supply
24	NW	24	"	"		"	1417	50	N.A.	-40	1377	50	1367			1	N.	
25	SE	24	"	"		dug	1561	70	NA	-57	1504	70	1491		hard,iron		S.	Sufficient supply
26	S.W.	27	"	"		bored	1403	90	NFA	-22	1381	90	1313		" ,clear	1	N.	
27	NE.	28	"	"		"	1420	100	N.F.A.	-25	1395	100	1320		" , "	1	S.	Sufficient supply.
28	NW.	30	"	"		"	1427	95	N.F.A.	-25	1402	95	1332	fine sand	" , "		D.S.	" "
29	SE	30	"	"		"	1447	30	NA	-3	1444	30	1417		" , "	1	DS	Sufficient for 25 head only

* All elevations in feet above sea-level
\# Sample taken for analysis

\+ Classification. F.A.–Flowing Artesian
N.F.A.–Non-Flowing Artesian
N.A.–Non-Artesian
I.N.A.–Intermittent Non-Artesian

° Use: S–Stock I–Irrigation M–Municipal D Domestic
N–Not used G–Greenhouse or Garden

WELL RECORDS TOWNSHIPS 11 to 14 RANGES 18 to 21 WEST OF Princ. MER. PROVINCE MANITOBA

Well No.	¼	Sec	Tp	Rge	Owner	Type	Elevation *	Depth (Feet)	Classification +	Water Level: Above (+) Below (-) Surface	Water Level: Elev *	Principal Water Bearing Bed: Depth (Feet)	Principal Water Bearing Bed: Elev. *	Geological Horizon	Water: Quality	No. of dugouts (Temp °F)	Use °	REMARKS
30	SE	31	11	20		bored	1433	53	NA	-15	1418	53	1380	fine sand	hard, alkali		N	
31	SW	34	11	"		"	1423	90				90	1333		" ,	1		No supply
32	NW	34	"	"			1448	96	NA	-66	1382	96	1352		" , iron	1	DS	Sufficient for 10 head only
33	NW	35		"		dug	1453	62	NA	-12	1441	62	1391		" ,		D.S.	Sufficient supply
34	S.E.	36	"	"		drilled	1565	90				90	1475	clay	" , alkali	1	N.	Too alkali.
1	SW	1	12	20	Blacksmith shop	drilled	1462	125	NFA	-25	1437	125	1337	clay	hard alkali		DS	Sufficient supply
2	SW	1	"	"		bored	1454	42	NA	-18	1436	42	1412	fine sand	"		S	Well in ravine for drinking water
3	NW	1	"	"		"	1493	80	NA	15	1478	80	1413	sand	" , iron		DS	Sufficient supply
4	NE	2	"			"	1493	120	NFA	-30	1463	120	1373	gravel	" ,	1	DS	Sufficient for 30 head
5	SE	2	"			"	1474	53	NA	-16	1458	53	1421		" , clear		DS	Sufficient supply.
6	NE	3	"	"			1479	130	NA	-90	1389	130	1349	fine sand	"		DS	
7	NE	3	"				1481	40	NA	35	1446	40	1441		" , "		S.	No supply
8	N.E.	3	"	"		"	1477	80	N.A.	-40	1437	80	1397	fine sand	" , "		S.	
9	NW	3	"	"		dug	1482	50	N.A.	-25	1457	50	1432	clay	" , iron		S	Sufficient supply
10	NW	4	"	"		"	1478	37	N.A.	-9	1469	37	1441		" , "		D.S.	" "
11	N.E.	4	"	"		drilled	1464	74	N.A.	-50	1414	74	1390	clay	" , "		D.S.	" "
12	N.E.	5	"	"		dug	1470	48	N.A.	-16	1454	48	1422		" , alkali		D.S.	" "
13	N.W.	7	"	"		bored	1538	67	N.F.A.	-10	1528	67	1471	clay	" , iron	1	S.	" "
14	SE	8	"	"		dug	1480	54	NA	-20	1460	54	1426	fine sand	" , "	1	DS	Sufficient for 50 head
15	SE	10	"	"		bored	1541	24	NA	-19	1522	24	1517		"		DS	Sufficient supply
16	NW	10	"			dug	1530	48	NA	-6	1524	48	1482		" , alkali		S	Sufficient for 50 head.
17	SW	11				bored	1504	70	NFA	-15	1489	70	1434	black sand	" , iron		D.S	Sufficient supply.
18	S.E.	12	"	"		"	1522	80	N.A.	-20	1502	80	1442		" , "		D.	" "
19	NW	13	"	"		"	1592	18	NA	-15	1577	18	1574	gravel	" , alkali		N	Sufficient for 6 horses only
20	SE	13	"	"		"	1572	78	NA	20	1552	78	1494	fine sand	" , iron	1	S	" 175 head in dry years
21	SW	14	"	"		"	1594	28	NA	-12	1582	28	1566	fine sand	" , "		DS	Sufficient supply
22	S.E.	15	"	"			1564	33	NA	-10	1554	33	1531		" , clear		DS	Not sufficient
23	NW	17		"		drilled	1597	52	NA	46	1551	52	1545	clay	"	1	S	Sufficient for 15 head only
24	SW	18	"			dug	1575	42	NA	40	1535	42	1533	sand	"		D	Two such wells
25	WW	22	"			bored	1687	98				98	1589	fine sand		1		Dry hole at time of interview
26	NE	24	"			dug	1628	10	NA	-7	1621	10	1618	sand	hard, clear		DS	Sufficient for 20 head
27	SW	24	"	"		dug	1596	10	NF	-7	1589	10	1586	gravel	" , "	1	D	Sufficient supply.
28	SE	25	"	"		bored	1661	40	NA	33	1628	40	1621	"	" , iron		S	Sufficient for 30 head
29	NE	33	"			dug	1646	37	NA	32	1614	37	1609	"	" , clear	1	DS	Sufficient supply.

* All Elevations in feet above sea level
\# Sample taken for analysis

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WELL RECORDS TOWNSHIPS 11 to 14 RANGES 18 to 21 WEST OF Princ. MER PROVINCE MANITOBA

Well No.	LOCATION ¼	Sec.	Tp.	Rge.	Owner	DESCRIPTION Type	Elevation *	Depth (Feet)	Classification +	WATER LEVEL Above (+) Below (-) Surface	Elev. *	PRINCIPAL WATER BEARING BED Depth (Feet)	Elev. *	Geological Horizon	WATER Quality	No. of dugouts	Use °	REMARKS
30	NW	24	12	20		bored	1636	60	NA	-40	1596	60	1576	clay	hard, iron		D S	Sufficient supply
31	NW	26	"	"		dug	1638	12	NA	-9	1629	12	1626	fine sand	" alkali		D S	Sufficient for 25 head
32	NW	27	"	"		bored	1642	36	N.A.	-12	1630	36	1606	gravel.	" , iron.		D.S.	Two bored wells
33	S.E.	28	"	"		"	1654	30	N.A.	-24	1630	30	1624	sand.	" , clear		D.S.	300 gals/day
34	NW	28	"	"		"	1613	32	N.A.	-16	1597	32	1581	clay	" , iron		D.S.	Sufficient supply.
35	NE	34	"			dug	1682	48	NA	-40	1642	48	1634	gravel	" , clear		D S	Sufficient for 150 head
36	NW	35	"	"		"	1682	40	N.A.	-38	1644	40	1640	fine sand.	" , alkali	1	N.	
1	NW	1	13	20		dug	1673	16	NA	-13	1660	16	1657	gravel	hard, clear		D S	Sufficient supply
2	S.E.	3	"	"		"	1663	16	N.A.	-8	1655	16	1647	gravel.	" , "		D.S	Sufficient for 40 head.
3	S.E.	6	"	"		"	1574	70	N.A.	-50	1524	70	1504	clay	" , "	1	D.	Not sufficient.
4	NE.	10	"	"		"	1593	18	N.A.	-8	1585	18	1575	fine sand.	" , "		D.S	Sufficient for 6 head only.
5	N.E.	11	"	"		"	1631	16	N.A.	-1	1630	16	1615		" , "		D.S.	Sufficient supply.
6	NE.	12	"	"		bored	1662	18	N.A.	-15	1647	18	1644	gravel	" , "		D.S.	Sufficient for 30 head.
7	N.W.	14	"	"		dug	1576	12	N.A.	-10	1566	12	1564	clay	" , "		D.S.	Sufficient supply.
8	SE	19		"		"	1709	15				15	1694	clay	" , "	1	D	"
# 9	SW.	19	"	"		drilled	1717	360	N.F.A.	-25	1692	360	1357	shale at 358	" , iron		D.S	
10	NW.	22	"	"		dug	1631	19	N.A.	-10	1621	19	1612	clay	" , clear	1	D.	
11	SE.	25	"	"		"	1596	20	N.A.	-5	1591	20	1576		" , alkali	1	N.	
12	SW	26	"	"		"	1575	14	NA	-2	1573	14	1561	sand	, clear	2	D S	Sufficient supply
13	S.W.	27	"	"		"	1644	10	N.A.	-8	1636	10	1634	fine sand.	" , "	1	D	" "
14	S.E.	28	"	"		"	1671	10	N.A.	-4	1667	10	1661	"	" , "	1	D.	" "
15	SE	30	"	"		drilled	1764	115	NFA	-7	1757	115	1649	shale at 115		1		Only lasted 1 month and then went dry
16	NW	30	"	"		"	1760	100	NFA	-15	1745	100	1660	clay	hard, iron		S	Sufficient supply
17	S.W.	32	"	"		"	1781	90	N.A.	-30	1751	90	1691	"	" , "	1	D.S.	Sufficient for 40 head.
18	SE	32	"	"		bored	1781	74	NA	-20	1761	74	1707		, clear		S	Sulphur odour to water
19	S.E.	34	"	"		"	1738	27	N.A.	-4	1734	27	1711	"	" , alkali	1	N.	Too alkali.
20	S.E.	35	"	"		dug	1658	12	NA	-10	1648	12	1646	sand	" , clear		D.S	Sufficient supply
21	NW.	36	"	"		bored.	1688	58	N.F.A.	-6	1682	58	1630		" , "		N	
1	NE.	3	14	20		dug	1776	8	NA.	-5	1771	8	1768	gravel	hard clear		D S	Sufficient supply
2	NW	4		"		drilled	1810	118	NFA	-18	1792	118	1692	clay		1	N	
3	NE	5	"	"		"	1826	63	NA	-30	1796	63	1763	"	hard, iron		S	
4	NE.	6	"	"		"	1810	150	N.F.A.	-27	1783	150	1660	"	" , "		S	Sufficient supply.
5	NE	7	"	"		"	1821	54	FA	+2	1823	54	1767	"	"		S	Dug well at house 16' deep

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# Sample taken for analysis

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WELL RECORDS TOWNSHIPS 11 to 14 RANGES 18 to 21 WEST OF Princ. MER PROVINCE MANITOBA

Well No	LOCATION ¼	Sec	Tp	Rge	Owner	DESCRIPTION Type	Elevation #	Depth (Feet)	Classification +	WATER LEVEL Above (+) Below (−) Surface	Elev. *	PRINCIPAL WATER-BEARING BED Depth (Feet)	Elev. *	Geological Horizon	WATER Quality	Temp (in °F) No. of dugouts	Use o	REMARKS
6	N.W.	8	14	20		drilled	1835	84	N.F.A.	-10	1825	84	1751	clay			N.	
7	N.W	9	"	"		bored	1820	33	N.A.	-8	1812	33	1787	sand.	hard, iron		D.S.	Sufficient supply
8	N.E	13	"	"		dug	1813	18	N.A.	-7	1806	18	1795			1.	N.	
9	N.E.	14	"	"		"	1824	40	N.A.	-20	1804	40	1784	clay	hard, iron	1	N.	Sufficient supply
10	S.W.	15	"	"		drilled	1852	65	N.A.	-20	1832	65	1787	"	", alkali		S	Sufficient for 40 head.
11	N.W.	15	"	"		dug	1873	60	N.A.	-25	1848	60	1813	"	", iron	1	S.	Sufficient supply.
12	N.E.	16	"	"		drilled	1874	60	N.A.	-30	1844	60	1814	"	", "		D.S	Sufficient for 40 head.
13	N.W.	16	"	"		"	1849	68	N.A.	-15	1834	68	1781	"	", "		D.S.	Sufficient supply
14	S.E.	16	"	"		"	1838	60	N.A.	-15	1823	60	1778	"	", "		D.S	Sufficient for 50 head.
15	S.W.	17	"	"		bored	1838	70	N.A.	-20	1818	70	1768	gravel.	", "		D.S	Sufficient supply.
16	N.W.	17	"	"		dug	1841	28	N.A.	-12	1829	28	1813	"	", clear		D.S.	Sufficient for 20 head.
17	N.E.	18	"	"		bored	1850	60	N.A.	-30	1820	60	1790	"	", "		D.S	" " 40 "
18	N.W.	18	"	"		dug	1858	44	N.A.	-25	1833	44	1814	clay	", iron		D.S	" " 40 "
19	S.E.	19	"	"		bored	1849	80	N.A	-23	1826	80	1769	gravel.	", alkali		D.S	Sufficient supply.
20	S.W.	19	"	"		dug	1868	44	N.A.	-29	1839	44	1824		", iron		D.S	" "
21	S.W.	21	"	"		"	1871	46	N.A.	-40	1831	46	1825	gravel.	", clear		D.S.	" "
22	S.W.	22	"	"		"	1879	65	N.A.	-20	1859	65	1814		", iron		S.	Sufficient for 30 head.
23	N.E.	26	"	"		drilled	1907	110	F.A.	0	1907	110	1797		", "		D.S.	" supply
24	S.W.	27	"	"		bored	1894	68				68	1826	clay	", "	1	S.	Sufficient for 40 head.
25	N.W	28	"	"		dug	1899	40	N.A	-4	1895	40	1859		, clear		D	" supply
26	S.E.	28	"	"		"	1884	40	N.A.	-35	1849	40	1844	clay	", "		D.S	Sufficient for 30 head.
27	S.W.	28	"	"		drilled	1881	200				200	1681		", iron		D.S	Sufficient supply
28	N.E.	29	"	"		"	1882	150				150	1732		", clear		D.	Not sufficient.
29	N.W.	30	"	"		dug	1886	32	N.A.	-18	1868	32	1854		", "		D.S.	Sufficient for 40 head.
30	S.W	30	"	"		bored.	1879	33	N.A.	-7	1872	33	1846		", "		N.	
31	N.E.	31	"	"		"	1912	82	N.A.	-35	1877	82	1830	clay	", "		D.S	Sufficient supply.
32	S.W.	32	"	"		dug	1893	61	N.A.	-16	1877	61	1832		", iron		D.S	" "
33	S.E.	32	"	"		bored.	1903	20	N.A.	-4	1899	20	1883	fine sand.	", "		D.S	" "
34	N.E.	33	"	"		dug	1908	70	N.A.	-20	1888	70	1838	clay	", "		D.S	" "
35	N.E.	35	"	"		bored.	1933	64	N.A.	-15	1918	64	1869	gravel.	", clear		D.	" "
36	N.W.	36	"	"		drilled.	1735	60	N.A.	-40	1695	60	1675		", iron		S.	Sufficient for 20 head.
1	N.E.	10	11	21		dug	1416	34	N.A.	-30	1386	34	1382	sand.	hard, clear		D	Sufficient supply.
2	N.E.	11	"	"		drilled	1405	165	N.A.	-35	1370	165	1240	fine sand.	soft, iron			Not sufficient.
3	N.W	12	"	"		dug	1313	26	N.A.	-18	1295	26	1287	sand	hard,		D.S	Sufficient supply.

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Well No.	LOCATION ¼	Sec.	Tp	Rge.	Owner	DESCRIPTION Type	Elevation *	Depth (Feet)	Classification +	WATER LEVEL Above (+) Below (-) Surface	Elev. *	PRINCIPAL WATER-BEARING BED Depth (Feet)	Elev. *	Geological Horizon	WATER Quality	No. of dugouts	Use °	REMARKS
4	NW	20	11	21		dug	1508	102	NA	-100	1408	102	1406		hard, clear		DS	Sufficient supply.
5	S.W.	24	"	"		"	1463	10	N.A.			10	1453	sand.	" , "		D.S.	" "
6	N.E.	25	"	"		"	1465	65				65	1400		" , "		S.	" "
7	N.E.	27	"	"		"	1499	80	N.A.	-78	1421	80	1419		" , "		S.	Sufficient for 70 head
8	N.W.	36	"	"		"	1486	20	N.A.	-17	1469	20	1466		" , "		D.S.	Sufficient supply.
9	S.E.	36	"	"		bored	1464	32	N.A.	-10	1454	32	1432	sand.	" , "		D.	" "
10	N.E.	36	"	"		dug	1476	12	N.A.	-5	1471	12	1464	clay	" , "		D.	" "
1	S.W.	1	12	21		dug	1477	10	N.A	-2	1475	10	1467	fine sand	hard, clear		DS	Sufficient for 50 head.
2	N.E.	2	"	"		"	1488	14				14	1474	" "	" , "		D.S.	Sufficient supply.
3	N.E.	6	"	"		"	1519	89	N.A.	-56	1463	89	1430		" , "		D.S.	Sufficient for 50 head.
4	N.E.	12	"	"		drilled	1554	60				60	1494		" , "	1	N.	Used to water 30 head.
5	N.E.	13	"	"		dug	1536	20	N.A.	-15	1521	20	1516		" , "		D.S.	Sufficient supply.
6	N.W.	20	"	"		"	1557	7	N.A.	-3	1554	7	1550	fine sand.	" , "		D.S.	" "
7	S.W.	23	"	"		"	1585	40	N.A.	-36	1549	40	1545	sand.	" , "		D.	" "
8	S.E.	25	"	"		"	1611	17	N.A.	-13	1598	17	1594	"	" , "		D.	" "
9	N.W.	25	"	"		"	1589	7	N.A.	-3	1586	7	1582	gravel	" , "		D.	"
10	S.E.	27	"	"		"	1587	24	N.A.	-22	1565	24	1563	sand.	" , "	1	D.	"
11	N.W.	27	"	"		"	1585	10	N.A.	-3	1582	10	1575	fine sand	" , "		D.	"
12	N.W.	28	"	"		"	1573	14	N.A.	-7	1566	14	1559	sand.	" , "	1	D.	"
13	S.W.	29	"	"		"	1570	32	N.A.	-13	1557	32	1538		" , "		N.	
14	N.W.	30	"	"		"	1583	16	N.A.	-12	1571	16	1567	fine sand.	" , "		D.S.	Sufficient for 30 head.
15	S.E.	32	"	"		"	1587	28	N.A.	-8	1579	28	1559	gravel.	" , "		D.S.	Sufficient supply.
16	S.W.	33	"	"		bored	1577	13	N.A.	-7	1570	13	1564		" , "	1	D.	" "
17	N.E.	33	"	"		"	1611	16	N.A.	-7	1604	16	1595	clay	" , "	1	D.S.	" "
18	N.W.	34	"	"		"	1616	8	N.A.	-4	1612	8	1608	gravel.	" , "	1	D.	" "
19	S.E.	34	"	"		dug	1610	34	N.A.	-19	1591	34	1576	clay	" , iron.		D.S.	" "
20	S.W.	36	"	"		"	1614	27	N.A	-7	1607	27	1587	sand	" , "	1	DS	Sufficient for 30 head
1	S.W.	3	13	21		bored	1640	30	N.A.	-18	1622	30	1610	clay	hard, clear	1	N	Drilled dry holes 300 feet
2	S.E.	3	"	"		dug	1639	18	N.A.	-10	1629	18	1621	gravel	" , alkali	1	S.	Sufficient supply.
3	N.E.	4	"	"		"	1668	35	N.A.	-27	1641	35	1633	clay	" , clear	1	D.	Sufficient supply.
4	S.E.	4	"	"		bored	1640	30	N.A.	-14	1626	30	1610	sand	" , "	1	DS	" "
5	N.E.	6	"	"		dug	1644	14	N.A.	-9	1635	14	1630	sand.	" , "		D.S.	Sufficient for 10 head.
6	S.E.	7	"	"		"	1661	40	NA	-10	1651	40	1621		" , "		DS	" 25 "

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N–Not used G–Greenhouse or Garden

WELL RECORDS TOWNSHIPS 11 to 14 RANGES 18 to 21 WEST OF Princ. MER. PROVINCE MANITOBA

Well No.	LOCATION ¼	Sec	Tp	Rge	Owner	DESCRIPTION Type	Elevation *	Depth (Feet)	Classification +	WATER LEVEL Above (+) Below (−) Surface	Elev. *	PRINCIPAL WATER-BEARING BED Depth (Feet)	Elev. *	Geological Horizon	WATER Quality	No. of dugouts ~~Temp (in °F)~~	Use °	REMARKS
7	N.W.	10	13	21		bored	1678	7	N.A.	-5	1673	7	1671	clay	hard, clear		D	Sufficient supply
8	S.E.	13	"	"		dug	1644	14	N.A.	-4	1640	14	1630	clay	" , "		N	
9	N.W.	13	"	"		"	1724	12	N.A.	-7	1717	12	1712	"	" , "	1	D S	Drilled a dry hole 150 feet
10	N.E.	14	"	"		"	1732	40	N.A.	-30	1702	40	1692	gravel	" , "	1	D S	Watered 15 head in dry years
11	S.W.	15	"	"		"	1674	11	N.A.	-8	1666	11	1663	"	" ,		D S	Sufficient supply.
12	N.W.	17	"	"		drilled	1705	120	N.F.A.	-18	1687	120	1585	clay	" , iron		D S.	Sufficient for 15 head.
13	S.W.	19	"	"		dug	1719	40	N.A.	-30	1689	40	1679	sand	" , clear		D.S.	" " 30 "
14	S.E.	20	"	"		bored	1736	27	N.A.	-25	1711	27	1709		" , iron		D.	A drilled well 147 feet
15	S.E.	21	"	"		"	1726	45	N.A.	-44	1682	45	1681	sand	" , clear		D	deep, for stock supply.
16	N.W.	21	"	"		drilled	1740	138	N.F.A	20	1720	138	1602	shale	" , iron		S.	Sufficient for 50 head.
17	N.W.	22	"	"		"	1745	125	N.F.A.	-20	1725	125	1620		" , "		S.	" " 50 "
18	S.W.	23	"	"		dug	1732	30				30	1702	clay	" , clear	1	S.	Sufficient supply.
19	N.W.	24	"	"		drilled	1756	100	N.A.	-45	1711	100	1656		" , iron		S.	Sufficient for 45 head.
20	N.W.	27	"	"		dug	1753	40	N.A.	-6	1747	40	1713		" , "		S.	Not sufficient
21	N.E.	27	"	"		"	1771	50	N.F.A.	-3	1768	50	1721		" , clear		D.S.	Sufficient supply.
22	S.W.	28	"	"		"	1776	50				50	1726		" , iron		N.	
23	S.E.	30	"	"		"	1749	37	N.A.	-7	1742	37	1712		" , "		S.	Sufficient for 20 head.
24	N.W.	30	"	"		"	1765	30	N.A.	-18	1747	30	1735		" , clear		D.S	Sufficient supply.
25	S.W.	32	"	"		drilled	1751	90	N.A.	-12	1739	90	1661		" , iron		D.S	Sufficient for 25 head.
26	N.E.	32	"	"		dug	1770	31				31	1739	gravel	" , clear		D S	" " 20 "
27	N.W.	33	"	"		drilled	1776	76	N.A.	-12	1764	76	1700		" , iron		S.	Sufficient supply.
28	N.W.	34	"	"		dug	1788	14	N.A.	-10	1778	14	1774		, alkal.		N.	
29	S.E.	35	"	"		"	1771	21	N.A.	-10	1761	21	1750		" , "		S	Sufficient for 10 head.
30	N.E.	35	"	"		"	1758	50	N.A.	-25	1733	50	1708		" , clear		S	Sufficient supply.
1	N.W.	1	14	21		drilled	1812	60	N.A.	-15	1797	60	1752	gravel	hard, iron		D S	Sufficient supply.
2	N.W.	4	"	"		"	1797	80				80	1717		" , "		D S	Sufficient for 40 head.
3	S.W.	6	"	"		dug	1768	29	N.A.	-19	1749	29	1739	gravel	" , "		S	" " 70 "
4	S.W.	7	"	"		drilled	1780	75	N.A.	-25	1755	75	1705	fine sand.	" , clear		D S	Sufficient supply.
5	S.E.	8	"	"		dug	1780	20	N.A.	-10	1770	20	1760	clay	" , iron		D S	Sufficient for 60 head.
6	S.W.	8	"	"		drilled	1784	135	N.F.A.	-10	1774	135	1649		" ,		D S	Sufficient supply.
7	N.E.	9	"	"		dug	1808	45	N.A.	-30	1778	45	1763	clay	, alkal.		D S	Sufficient for 50 head.
8	S.E.	9	"	"			1793	44	N.A.	-26	1767	44	1749	"	" , iron		D.S	Sufficient supply
9	N.E.	10	"	"		"	1848	60	N.A.	-30	1818	60	1788	sand.	" , "		D S	
10	S.W.	10	"	"		bored	1878	35	N.A.	-32	1846	35	1783	clay	" , "		N	Also a dug well 30 ft. deep.

* All elevations in feet above sea-level
\# Sample taken for analysis

\+ Classification: F. A.–Flowing Artesian
N. F. A.–Non-Flowing Artesian
N. A.–Non-Artesian
I. N. A.–Intermittent Non-Artesian

° Use S–Stock I–Irrigation M–Municipal D–Domestic
N–Not used G–Greenhouse or Garden

WELL RECORDS TOWNSHIPS 11 to 14 RANGES 18 to 21 WEST OF Princ. MER. PROVINCE MANITOBA

Well No	LOCATION ¼	Sec	Tp	Rge.	Owner	DESCRIPTION Type	Elevation *	Depth (Feet)	Classification +	WATER LEVEL Above (+) Below (-) Surface	Elev. *	PRINCIPAL WATER-BEARING BED Depth (Feet)	Elev *	Geological Horizon	WATER Quality	Temp. (in °F)	Use °	REMARKS
11	S.E.	11	14	21		dug	1808	30	N.A.	-9	1799	30	1778		hard, iron		D.S.	Sufficient supply.
12	S.E.	12	"	"		"	1828	47	N.A.	-7	1821	47	1781	clay	" , "		D.S.	" "
13	N.E.	13	"	"		"	1844	25	N.A.	-14	1830	25	1819		" , "		D.S.	" "
14	S.W.	14	"	"		drilled	1832	70	N.A.	-15	1817	70	1762		" , "		D.S.	Sufficient for 40 head.
15	S.W.	15	"	"		bored	1820	60				60	1760		" , "		D.S.	" " 35 "
16	S.E.	16	"	"		dug	1841	40				40	1801	gravel	" , clear		D.S.	
17	N.W.	16	"	"		"	1815	34	N.A.	-21	1794	34	1781		" , iron		S.	Sufficient for 10 head.
18	N.W.	17	"	"		"	1789	35	N.A.	-20	1769	35	1754		" , "		D.S.	Sufficient supply.
19	N.W.	18	"	"		"	1802	40	N.A.	-15	1787	40	1762		" , clear		D.S.	Sufficient for 15 head.
20	S.E.	19	"	"		"	1810	33	N.A.	-12	1798	33	1777		" , "		D.S.	Sufficient supply.
21	S.W.	19	"	"		bored	1800	45	N.A.	-20	1780	45	1755	clay	" , "		D.S.	Sufficient for 20 head only.
22	S.W.	20	"	"		dug	1792	32	N.A.	-10	1782	32	1760	clay	" , "		D.S.	" " 50 "
23	N.E.	21	"	"		"	1833	30	N.A.	-20	1813	30	1803	"	" , iron		D.S.	Sufficient supply.
24	N.W.	22	"	"		bored	1838	44	N.A.	-12	1826	44	1794	gravel	" , clear		D.S.	" "
25	S.E.	23	"	"		"	1858	47	N.A.	-27	1831	47	1811	clay	" , iron		D.S.	Sufficient for 15 head.
26	N.E.	24	"	"		drilled	1858	90?				90	1768		" , "		D.S.	" " 25 "
27	N.W.	25	"	"		dug	1872	32	N.A.	-14	1858	32	1840	clay	" , "		D.S.	Sufficient supply.
28	S.E.	26	"	"		bored	1869	55	N.A.	-20	1849	55	1814	gravel	" , "		D.S.	" "
29	S.W.	26	"	"		dug	1858	22	N.A.	-15	1843	22	1836	clay	" , clear		D.	" "
30	S.W.	27	"	"		dug	1858	42	N.A.	-22	1836	42	1816	sand	" , "		D.S.	" "
31	S.W.	29	"	"		"	1806	20	N.A.	-6	1800	20	1786		" , iron		D.	" "
32	N.E.	30	"	"		drilled	1819	135	N.F.A.	-20	1799	135	1684	shale	" , "		S.	Sufficient for 30 head.
33	S.W.	31	"	"		"	1831	155	N.F.A.	-15	1816	155	1676	shale at 151'	" , "		S.	Dug well 40 ft. for house.
34	S.W.	32	"	"		"	1827	165	N.A.	-40	1787	165	1662	shale	" , "		S.	Sufficient supply.
35	N.W.	32	"	"		dug	1843	36	N.A.	-8	1835	36	1807	gravel	" , "		D.	" "
36	N.W.	32	"	"		"	1843	30	N.A.	-6	1837	30	1813	"	" , "		D.	" "
37	S.E.	33	"	"		"	1853	38	N.A.	-18	1835	38	1815		" , "		D.S.	" "
38	S.E.	34	"	"		"	1860	85				85	1775	clay	" , "		D.S.	Sufficient for 20 head.
39	N.E.	35	"	"		"	1899	35	N.A.	-28	1871	35	1864	sand	" , "		D.S.	" " 15 "
40	N.E.	36	"	"		bored	1904	60	N.A.	-40	1864	60	1844		" , "		S.	" " 25 "

* All elevations in feet above sea-level
# Sample taken for analysis

+ Classification F. A.–Flowing Artesian
N. F. A.–Non-Flowing Artesian
N. A.–Non-Artesian
I. N. A.–Intermittent Non-Artesian

° Use S–Stock I–Irrigation M–Municipal D–Domestic
N–Not used G–Greenhouse or Garden

CANADA
DEPARTMENT
OF
MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

LEGEND

CENOZOIC

QUATERNARY

RECENT

5 — sand and gravel

PLEISTOCENE

4

3 — TILL

2 — gravel

1 — GROUND MORAINE — Till with of sand and gravel surface uneven

Geological boundary approximate

this area

FIGURE 1
MAP SHOWING TYPES OF OVERBURDEN

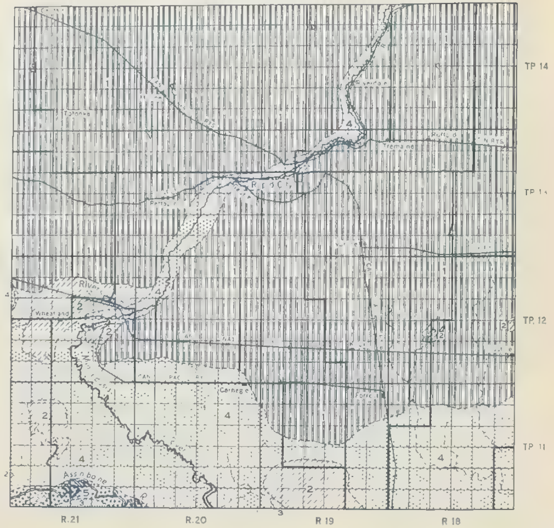
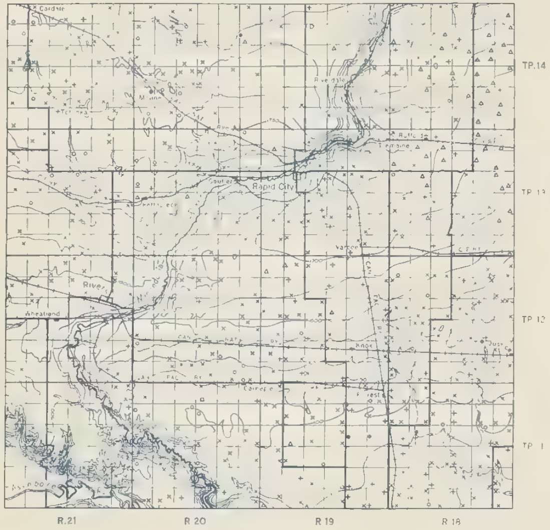


FIGURE 2
MAP SHOWING TOPOGRAPHY
AND LOCATION AND TYPES OF WELLS



LEGEND

WELL CLASS 1 — above the ground surface

WELL CLASS 2

WELL CLASS 3

is scant or lacking

DRY HOLE

Road

Railway

Contours

TOWNSHIPS 11-14, RANGES 18-21

WEST OF PRINCIPAL MERIDIAN

MANITOBA

Scale: 1 Inch to 4 Miles

4 0 4 8 12

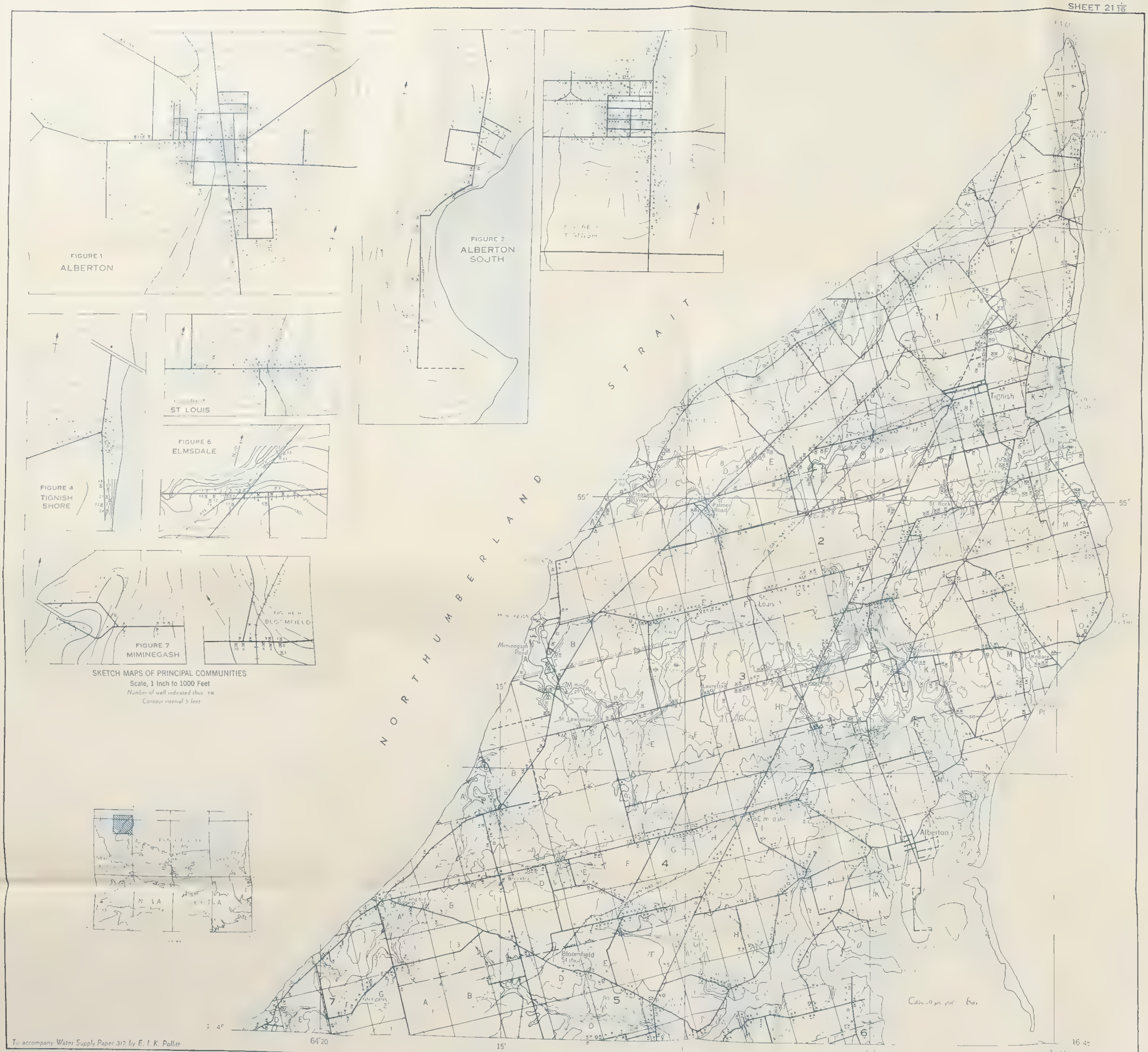
To accompany Water Supply Paper No. 313 "Rivers Area," by E. C. Halstead

Cartography by the Geological Cartography Division, 195-

CANADA
DEPARTMENT
OF
MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

SHEET 21 $\frac{1}{16}$



LEGEND

In drift / In bedrock — Flowing artesian wells, in which the water is under sufficient pressure to raise it above surface level

In drift / In bedrock — Non-flowing artesian wells, in which the water is under pressure but does not rise to the surface

In drift / In bedrock — Non-artesian wells, in which the water does not rise above the water-table

In bedrock — Intermittent, non-artesian wells, which dry up intermittently

In drift / In bedrock — Springs

NOTE. *The above symbols may not all appear within the limits of this map-area*

Lot subdivisions . . . . 1, 2 3 A B C

Approximate magnetic declination, 25° 00′ West

TOPOGRAPHY, AND LOCATION, AND TYPES OF WELLS

TIGNISH AREA

PRINCE COUNTY

PRINCE EDWARD ISLAND

Scale: One Inch to One Mile = $\frac{1}{63,360}$

Miles

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GEOLOGICAL SURVEY OF CANADA

LEGEND

SURFACE DEPOSITS

CENOZOIC
QUATERNARY
PLEISTOCENE

- 5 GLACIAL-LAKE DEPOSITS — Mostly clay and silt, some sand
- 4 GRAVEL DEPOSITS — Gravel laid down by glacial or post-glacial streams
- 3 END MORAINE — Till
- 2 GROUND MORAINE — Till

BEDROCK GEOLOGY

- Large areas of exposed bedrock

Approximate boundary between Edmonton (**A**) and Paskapoo (**B**) formations

Geological boundary (approximate)

FIGURE 1
MAP SHOWING BEDROCK FORMATIONS AND SURFACE DEPOSITS

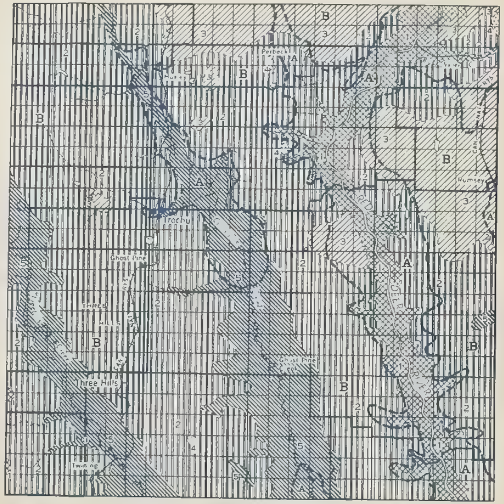
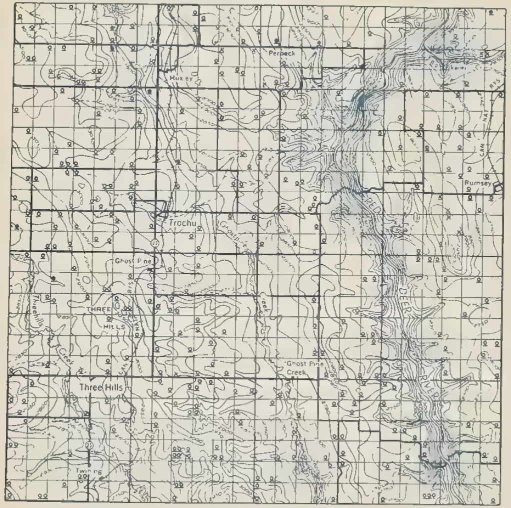


FIGURE 2
MAP SHOWING TOPOGRAPHY AND LOCATION AND TYPES OF WELLS



LEGEND

- **Wells, Class 1** Flowing artesian wells in which the water is under sufficient pressure to raise it above surface level
- **Wells, Class 2** Non flowing artesian wells in which the water is under pressure but does not rise to the surface
- **Wells, Class 3** Non artesian wells in which the water does not rise above the water table
- SPRINGS

NOTE A short dash under any symbol indicates that the well is in bedrock

Road
Railway
Contours (interval 50 feet)

TOWNSHIPS 31-34, RANGES 21-24

WEST OF FOURTH MERIDIAN

ALBERTA

Scale: 1 Inch to 4 Miles

4 0 4 8 12

To accompany Water Supply Paper 311, "Three Hills Area" by A. MacS. Stalker

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GEOLOGICAL SURVEY OF CANADA

LEGEND

SURFACE DEPOSITS

CENOZOIC

QUATERNARY

RECENT

SWAMP DEPOSITS

8 Muck

ALLUVIAL DEPOSITS

7 Clay, silt, sand, and gravel

PLEISTOCENE

CHAMPLAIN SEA DEPOSITS

MARINE BEACH DEPOSITS

6 Sand and gravel; may include some freshwater deposits

MARINE DEPOSITS

4 | 5 4, clay; may include some freshwater deposits
5, silt and sand; may include some freshwater deposits

GLACIO - FLUVIAL DEPOSITS

3 Kame; predominately sand, some gravel

GLACIAL DEPOSITS (1, 2)

2 Water - worked till; clay till with a large proportion of the finer material washed away; surface deposits, mainly sand and gravel

1 Clay till

BEDROCK FORMATIONS

PALÆOZOIC

ORDOVICIAN

D OTTAWA FORMATION: Pamelia beds; limestone, dolomite, shale, and thin - bedded sandstone

C ST. MARTIN FORMATION: limestone; minor shale and dolomite

B ROCKCLIFFE FORMATION: grey - green shale with lenses of grey sandstone

A OXFORD FORMATION: grey limestone, magnesium limestone and dolomite

Boulder accumulation, the frequency of 'o's indicates the relative number of boulders present on surface

Emerged marine shoreline

Gravel pit ... GP

Sand pit ... SP

Boundary of Bedrock formation

Outcrop

Area with bedrock occurring approximately 10 feet from surface, includes small outcrops too small to be plotted ... A

Quarry

Geology by E.B. Owen, 1949

FIGURE 1

MAP SHOWING SURFACE DEPOSITS AND BEDROCK FORMATIONS

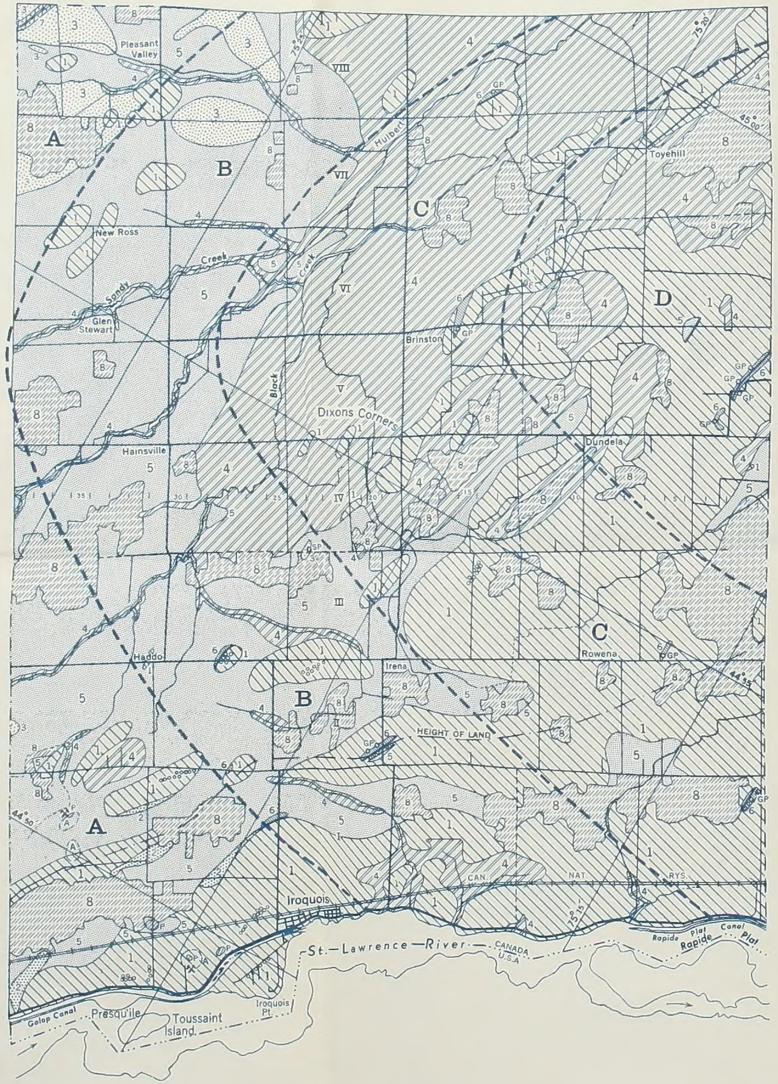
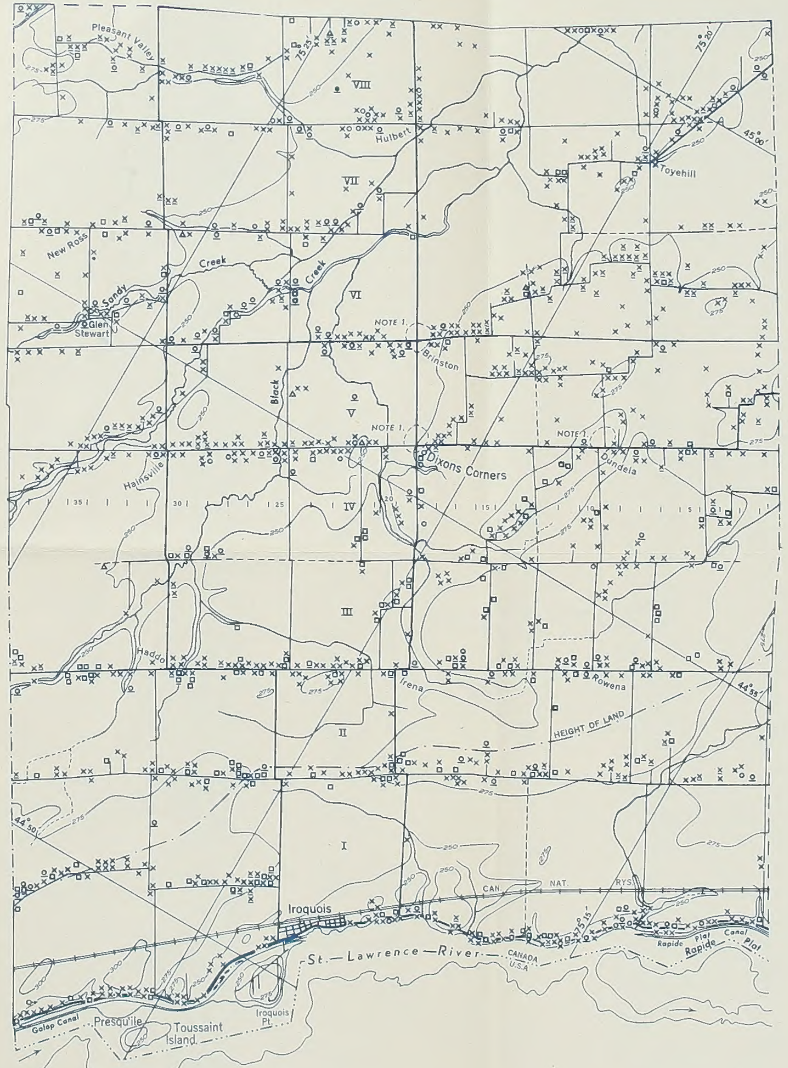


FIGURE 2

MAP SHOWING TOPOGRAPHY AND LOCATION AND TYPE OF WELLS



LEGEND

WELLS, CLASS 1. Flowing artesian wells, in which the water is under sufficient pressure to raise it above surface level (In drift; In bedrock)

WELLS, CLASS 2. Non - flowing artesian wells, in which the water is under pressure but does not rise to the surface (In drift; In bedrock)

WELLS, CLASS 3. Non - artesian wells; in which the water does not rise above the water - table (In drift; In bedrock)

WELLS, CLASS 4. Intermittent, non - artesian wells, which dry up intermittently (In drift; In bedrock)

DRY HOLES (In drift; In bedrock)

SPRINGS (In drift; In bedrock)

NOTE 1. Within the areas outlined about Brinston, Dixons Corners and Dundela, the wells are too closely spaced to be shown on this map

Contours, interval 25 feet ... 300

Concession and lot number ... VI. 15

To accompany Water Supply Paper 310 by E.B. Owen

PUBLISHED, 1951

MATILDA TOWNSHIP

DUNDAS COUNTY

ONTARIO

Scale: One Inch to One Mile = $\frac{1}{63,360}$

Miles

1 ¾ ½ ¼ 0 1 2 3